(Comparative anatomy)

Theoretical part

First term

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Comparative anatomy

Content

Comparative anatomy

INTRODUCTION

Defintion of comparative anatomy:

Is a branch of zoology deals with studying the relationships of the structure and origin of all organ systems of all forms in the animal kingdom.

Integumentary and exoskeletal system:

- The dermal system consists of skin and its derivatives such as: scales, feathers, claws, nails, horns and hoofs, the skin glands such as: mucous, sweat and poisonous glands.
- The integument covered all the surface of the body.
- The skin has many important functions:

  Protection, regulation, locomotion

Protochordata

The dermal system of Protochordata (Amphioxus)

Ex: ***Amphioxus lanceolatus***

The skin consists of two main layers:

1-Epidermis 2-Dermis

1-Epidermis

A single layer of columnar epithelium and among them there is a goblet cell

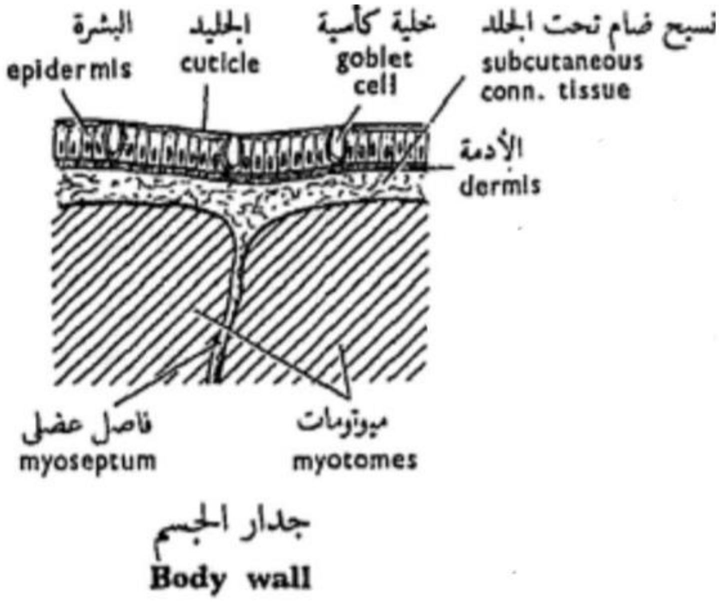
2- Dermis

Very thin and is composed of fine connective tissue.

3-Hypodermis

Below the dermis and it is a thin connective tissue which surrounded the muscles of the body wall or the myotomes and continued with the myosepta which found between the myotomes.

NOTE: There is no exoskeleton derivative in prechordata.



The dermal system of Higher Chordata

The general character of the skin

1-Epidermis

2- Dermis

3- Hypodermis

1- Epidermis (is ectodermal in origin) consists of three main layer

A-Stratum germinative (Malpagian layer)

B- Sratum mucosum.

C- Stratum cornium (Horney layer).

A-**Stratum germinative** (Malpagian layer)

Consists of columnar epithelium cells and in active state of division and profilate forming several layers called Sratum mucosum

B- Sratum mucosum.

Consists of several layers of squamous cells which transformed gradually into dead cells in their way to the surface by secreting a horney substance forming the Stratum cornium (Horney layer).

C-**Stratum cornium** (Horney layer):

Layer of dead cells

NOTE the derivatives of epidermis is horney structure

2-Dermis (is mesodermal in origin)

consists of two main layers:

1-Stratum laxum (external)

2-Compactum (internal)

1-Stratum laxum (external)

Consists of thin connective tissue which rich by blood vessels and nerve endings

2-Compactum (internal)

Consists of compact connective tissue and give the dermis some rigidity

NOTE 1- the derivatives of dermis is bony structure.

2-There is a chromatophores in dermis

3-Hypodermis

In perfict animal consists of two layer :

1-External :Adipose connective tissue to store lipids .

2-Internal :connective tissue that link between the skin and the

muscles .

EXOSKELETAL DERIVATIVES

- A-Glands
- **The glands**: are developed from epidermis and extend into the dermis, there are two types:

1-Unicellular 2- Multicellular

- **A) simple unicellular glands**: where one cell becomes specialized and secretory in function such as mucous and goblet cells
- B) **Compound "multicellular" glands** where the cells of stratum germinative invaginate into the dermis which opens on the surface of skin:
  - tubular type such as sweat and mammary glands
- - Alveolar type such as sebaceous and poisonous glands
- Poisonous glands found at the base of the pectoral spines or on the dorsal spines of some teleosts

1. **The epidermal exoskeleton**:- is produced as a result of the activity of the malpighian layer.

- It consist of flat horny cells which condence together forming a hard structures such as:
  - horny teeth of cyclostomes
  - horny scales of reptiles
  - feathers of birds
  - hairs of mammals
  - claws of some amphibians, reptiles, birds and some mammals
  - nails of human
  - horns of mammals

2. The dermal exoskeletal derivatives: it is produced by the mesenchymal cells which originate from the mesoderm such as :
- bony scales of bony fishes
- fin rays and fin spines of fishes.

3. The derivatives from both epidermis and dermis:
- Placoid scales of cartilagenous fishes
- True teeth of mammals

The dermal system of cyclostomes (Petromyzon)

1-The Epidermis is stratified epithelium, consists of

1-Active basal layer (stratum germinative)

2-Flattened cells (stratum mucosum)

3-Cuticle: It is a live

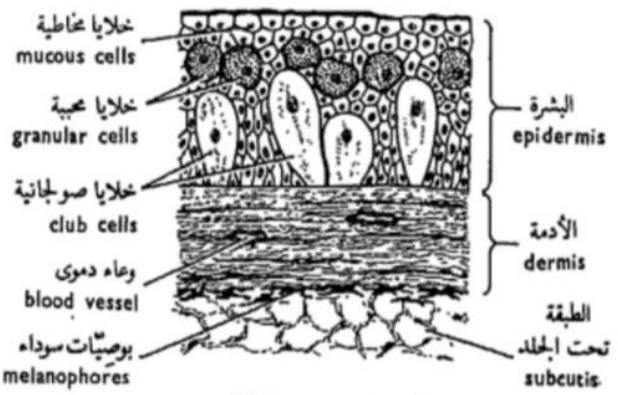
• The Epidermis is relatively thin and its cells is a live and covered by a cuticle or mucous .this mucous or glycoprotein eliminate the microscopic creature that clinging to the body .

• The epidermis ended by flattened cells while the cartilage and bony fishes ended by a distinct horny layer.

2-The Dermis It is less thickness than the epidermis and not

differentiated into two layer.

• The melanophores present below the dermis.



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V.S. of skin

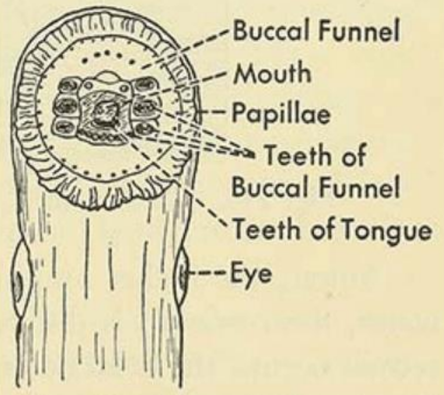


Fig. 145. Ventral view of head of *Petromyzon,* showing oral sucker with horny "teeth" and piston-like "tongue." (After Parker.)

The dermal system of Cartilagenous fishes

1- The epidermis mucous layer and more differentiated and give the horny layer

• The cells still a live

2-The dermis is more thickened and composed of two layers:

A-Stratum laxum

B-stratum compactum

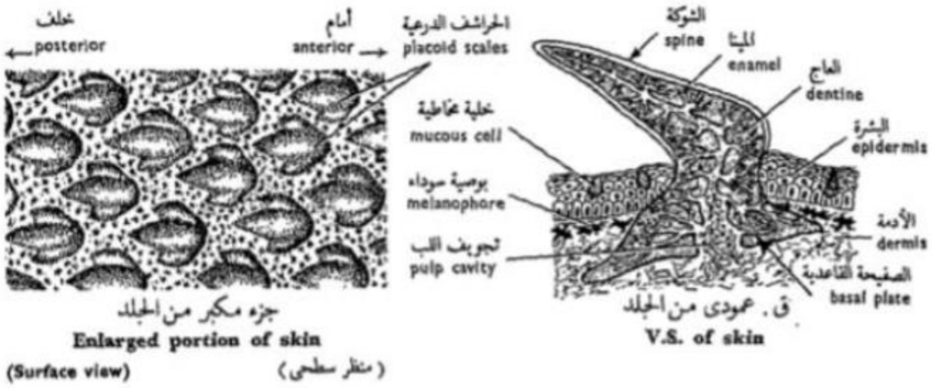
• The melanophores below the epidermis directly.

3-The hypodermis: There is no hypodermis.

Exoskeletal derivatives:

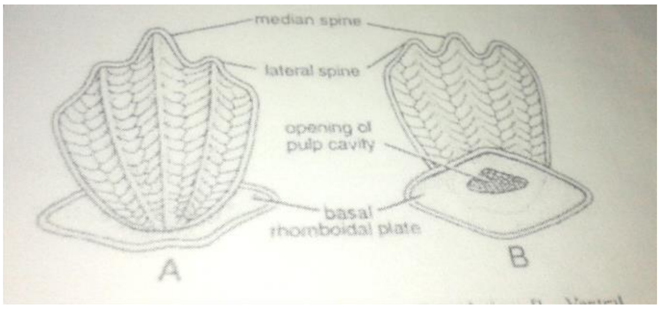
1- Dermal spine.

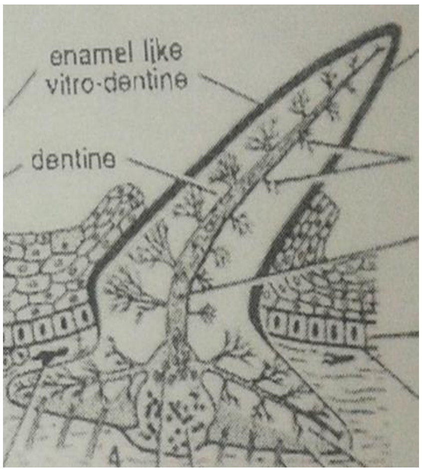
2- Mixed placoid scales and teeth.



The structure of placoid scale

- Consists of a basal plate inserted in the dermis and a spine projected outward through the epidermis. The basal plate or disc has two lobes and consists of hard dentine substance, while the spine composed of an inner dentine substance covered by a thin layer of more hard dentine called vitrodentine (enamel).





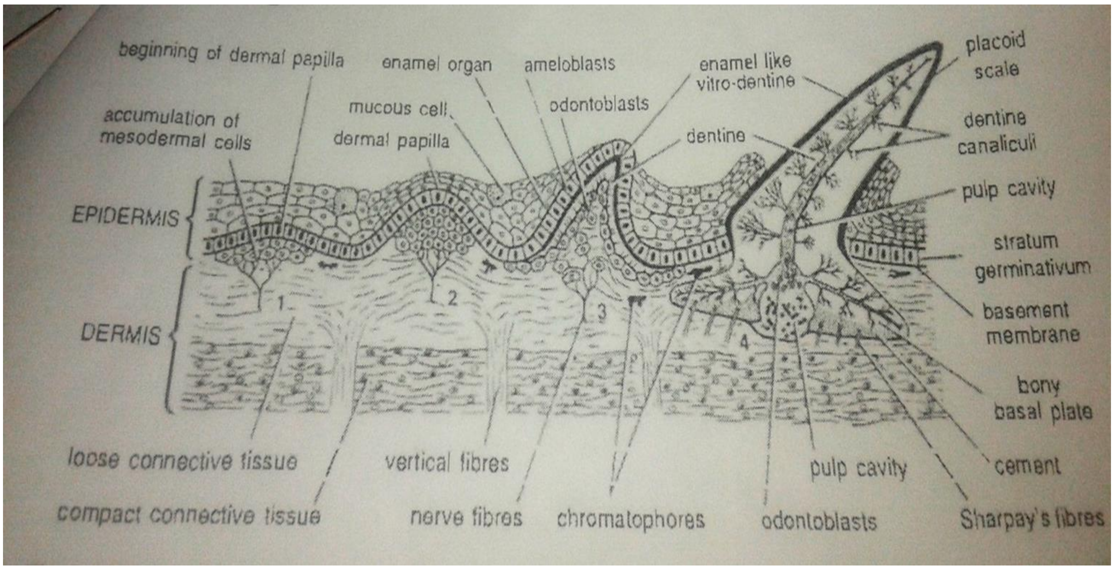
- In the center of the scale, there is a pulp cavity for the presence of blood vessels and nerve endings.
- The placoid scales grow to a certain size, then shed away and new scales replace the old ones.
- In most elasmobranches, these placoid scales are very small.

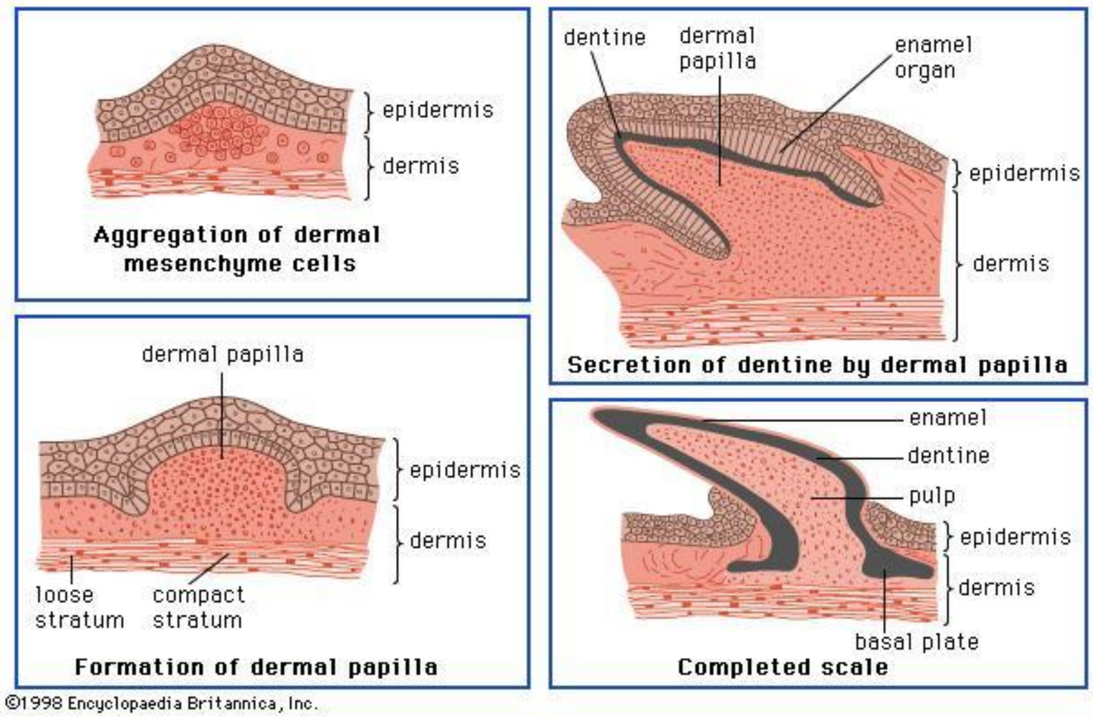
The development of placoid scale of dog fishes

- 1- The cells of the stratum germinative of epidermis at some places (future sites of placoid scales) become active.
- At the same time mesenchymal (mesodermal) cells of the dermis accumulate at these activated areas forming the dermal papillae
- 2- The cells of str. germ. of epidermis as well as the dermis in these areas evaginate to form conical projections.
- The mesenchymal cells of mesoderm arranged themselves to form a regular layer underneath the cells of str. germ. and parallel to them.
- 3- The active cells of str. germ. in contact with the dermal papilla differentiated into a tall columnar cells forming the enamel or ameloblasts (epidermal-cells).
- 4- At the same time the outer mesenchymal cells of the dermal papilla secrete another hard material on their outer border. This

material is called the dentine and the dermal cells which secrete it are known as the odontoblasts. The remaining part of the papilla constitutes the nutritive part in the pulp of the placoid scale

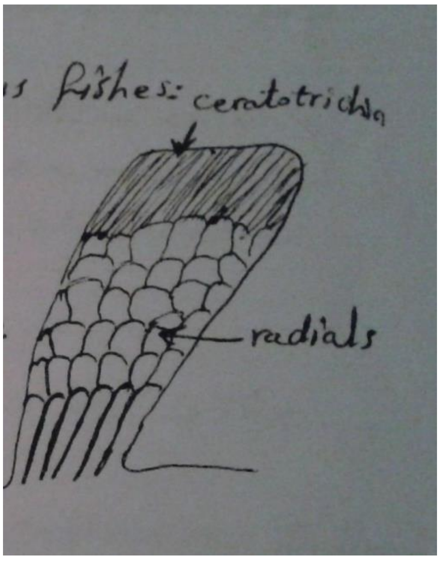
- 5- By the secretion of more dentine from the dermal papilla, the scale increases gradually in size and pushes itself in the epidermis, untill it pierces it and the spine becomes exposed externally and points posteriorly.
- 6- At the same time, more dentine is secreted at the base of the scale forming the basal plate which embeded in the dermis and enclosed the rest of the dermal papilla leaving a passage for blood vessels called the pulp cavity





Cerratotrichia of cartilagenous fishes

They are elongated hair-like fibrous connective tissue rods, these fin rays are in the form of simple and flixble rays of dermal origin. The dermal fin spines which found in sharks arise by the fusion of some fin rays.



The dermal system of bony fishes

The skin of bony fishes is nearly similar to that of cartilaginous fishes. The dermal exoskeletal derivatives are represented by the hard bony scales embedded in pouches in the dermis and overlapping on another from the hind and the lepidotrichia or bony fin rays.

The structure of bony scales

The bony scales are composed of bone, flate plates, formed from the dermis only, rarely shed away and they grow inside throughout the whole life of fish.

The bony scale grows by the addition of new layers of bones at its periphery.

In hot water and temperate seas, where there are no marked seasonal and food variations throughout the whole year, the lines of growth are of the same size. But in the case of cold water seas where food materials are very rare in winter, small layers are added in this season, while in summer where there is plenty of food, several and thicker layers of growth are added. So the age of fish can be known by count the summer and winter layers.

In some teleosts such as in the family of Anguillidae (eels) the scales are minute and embedded in the skin.

They are lacking in the common cat-fishes (Clarias, Bagrus), in the electric rays and some others.

: dermal system of bony fishes

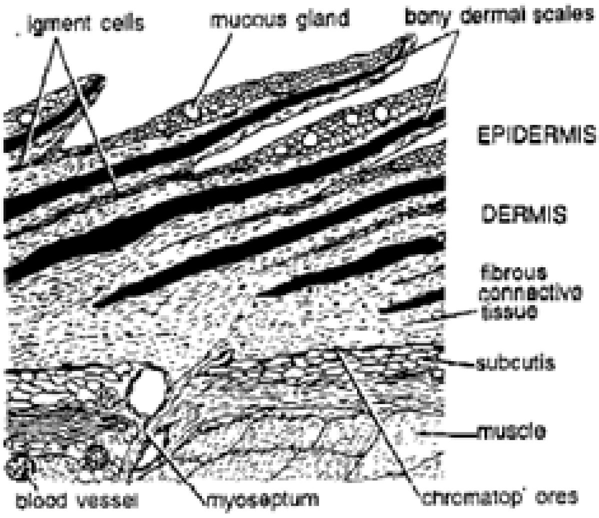


Fig. 7 Skin of a teleost fish in V. S.

<u>The development of bony scales in Teleostis</u>:

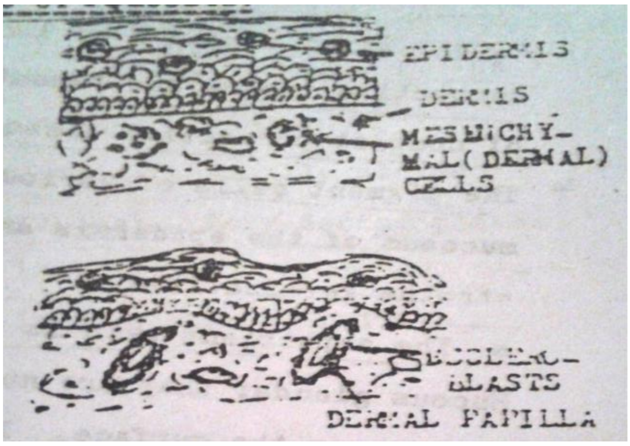
1-The scale begin to develop by an accumulation of special type of mesenchymal cells of dermis known as sceleroplasts below the epidermis this cell arrange themselves into pouch of small sac called the dermal papilla.

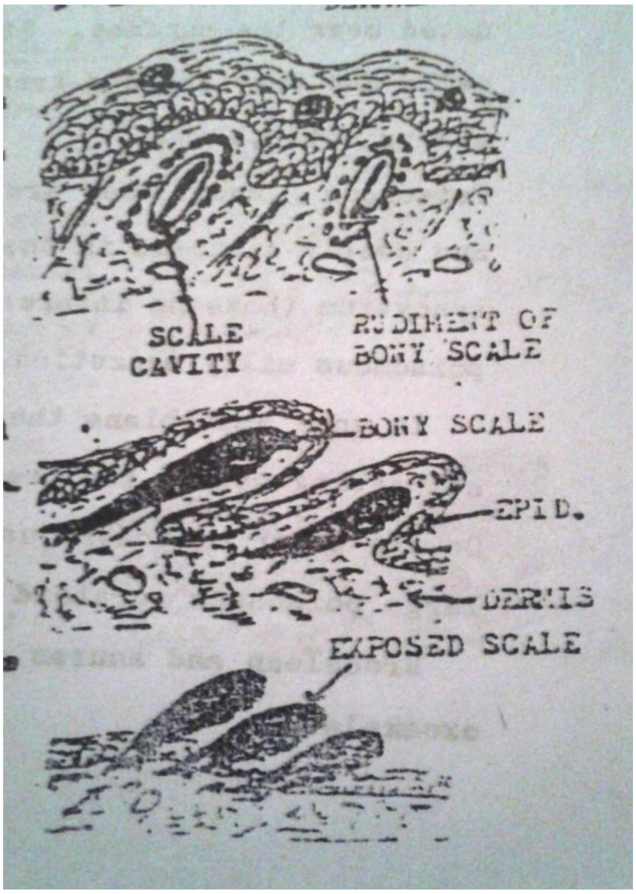
2- The active sceleroblasts of this papilla start to secrete a thin sheet of bone material at its inside to form the rudiment of bony scale A connective tissue strands from the dermal (scale bockets), separate the flattened bony scales.

3-By the secretion of more and more bone material, the scale increases in thickness and dimensions.

4- gradually the anterior end of each scale become deeper in the dermis, while the posterior end Grow toward the surface ,pushing the epiderm above which it becomes very thin .by this arrangement , the scales become overlapping each other

5.the epidermals either remain as a thin membrane covering the overlapping posterior edges of the scales or ruptures leaving the posterior edge of the scales exposed to outside.



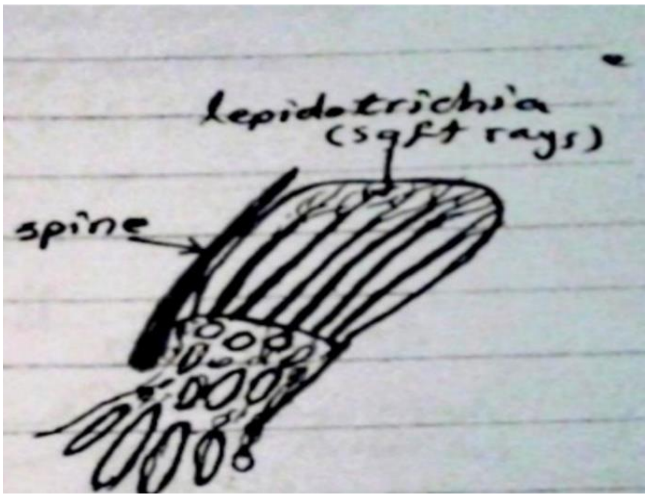


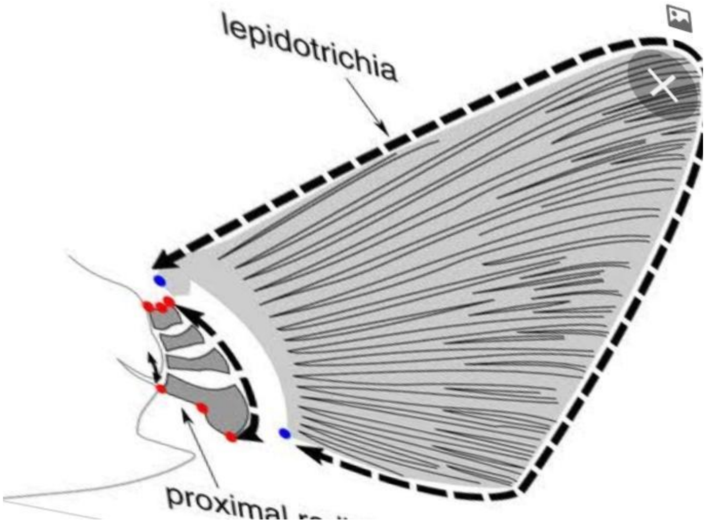
The lepidotrichia of the fin

These fin rays are also dermal in origin and supported the outer part of the fin and composed of bony material the lepidotrichia are long segmented and branched fin rays.

The development of these fin rays is similar to that of the bony scales. Each ray consists of modified scales joined end to end. Some of the bony fin rays fuse together to form hard spines.

Generally they are found at the anterior edges of various fins serve as mechanical support for the fin, and as organ of defense. Many taleastes possess a serious of anterior spiny rays, which support the dorsal fin in addition to the posterior soft rays.




lepidotrichia

Types of scales in fishes

- **Placoid scales**: These are characteristic of cartilagenous fishes only. Each placoid scale consists of a backwardly directed spine arising from a round basal plate embeded in dermis. Spine is made of enamel-like and dentine-like material. A pulp cavity inside spine opens through basal plate
- Placoid scales are closely set together in skin giving it a sandypaper like quality.
- **Ganoid scales**: Are rhomboid scales, thick, enclosed fitted side by side, in some cases they may overlap
- Composed of three layers: outer enamel-like material, midle dentine-like material and inner bony material.
- **Cycloid scales**: They are thin and flexible overlapping single plates , thicker in the centre and marked with several lines of growth which can be used for determining the age of the fish
- They are composed of a thin upper layer of bone and a lower layer of fibrous connective tissue. They are overlap each other. Each scale embedded in a small pocket of dermis
- They are found in lung fishes
- **Ctenoid scales:**
- These are characteristic of modern higher teleosteans, they are similar to cycloid scales in structure, their exposed free hind parts bear numerous small teeth or spines

As in cycloid scale is embedded in a small pocket in the dermis , the scale are obliquely arranged so that the posterior end of one scale overlap the interior edge of the scale behind it. .

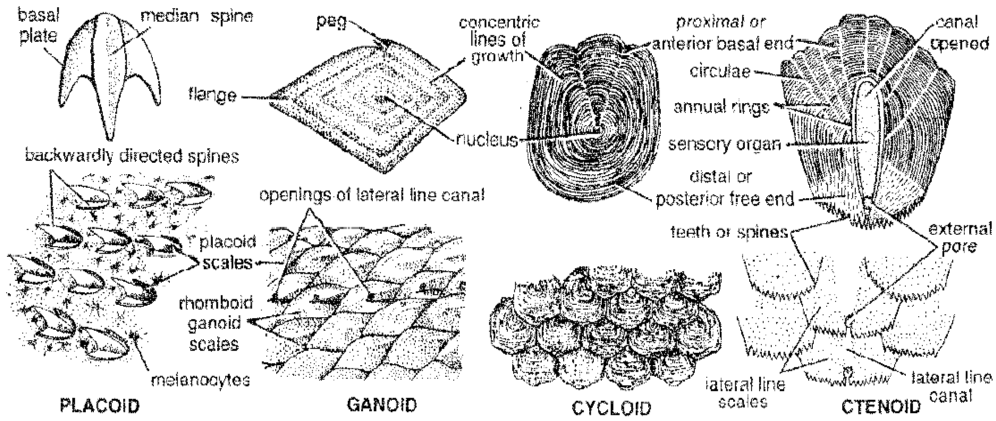
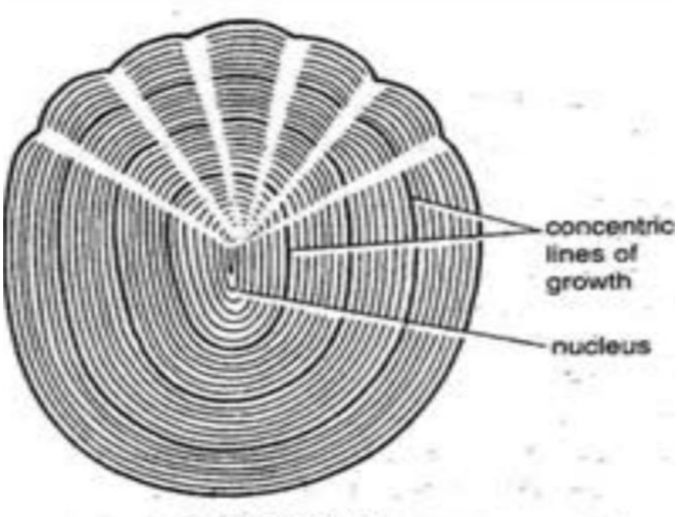


Fig. 5. Different types of dermal scales found in fishes. Lower row shows parts of skin with numerous scales. Upper row shows single scales.



Cycloid scale

The dermal system of Amphibia

The epiderm in the aquatic amphibian is thin, moist and thin stratified layer, while it is thick stratified in Terrestrial forms in which the corneal layer is very thick.

1-the epidermis

The horny layer appears first time and it is a thin one or two layer.

• In larva amphibia that lives in water have a live cuticle.

• In adult amphibia have dead horny layer

The skin of amphibia is richly supplied with blood vessels, since the skin is an important respiratory organ during the hypernation

The dermis is formed from two distinct layers, an outer spongy layer composed of loose connective tissue and beneath it there is a compact layer of compact connective tissue and strong parallel waivy fibers.

The pigment cells of various kinds are found in the structure mucousum of epidermis and in the dermis just beneath the stratum germinativum

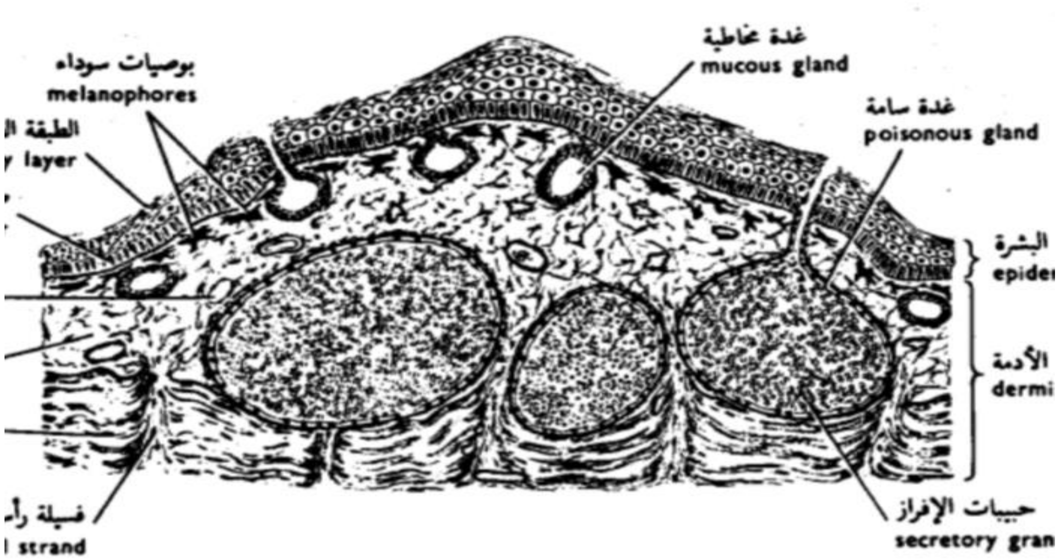
The amphibian skin is very rich by glands mucus glands: they are numerous and small in size and situated near the surface, its wall are composed of distinct cells, and they secrete transparent mucus which keep the skin always moist.

Poisonous glands: they are few in number and large in size and deeply situated in the skin. The gland is composed of syncytium (have no intercellular walls). They secrete a poisonous milky secretion.

In some amphibians there are granular poisonous glands, attracting sex in the breading seasons.

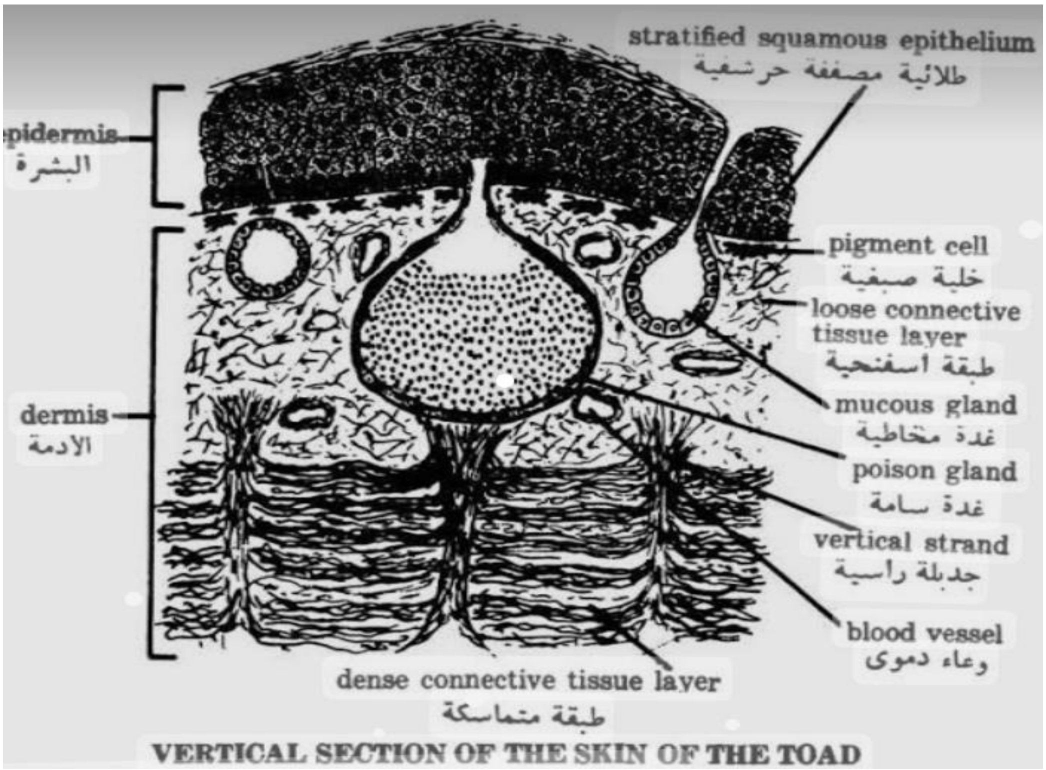
On the sides of the toads just behind the head, there are two large poisonous glands.

Urodelean and anuran amphibian posses naked skin, without exoskeleton.



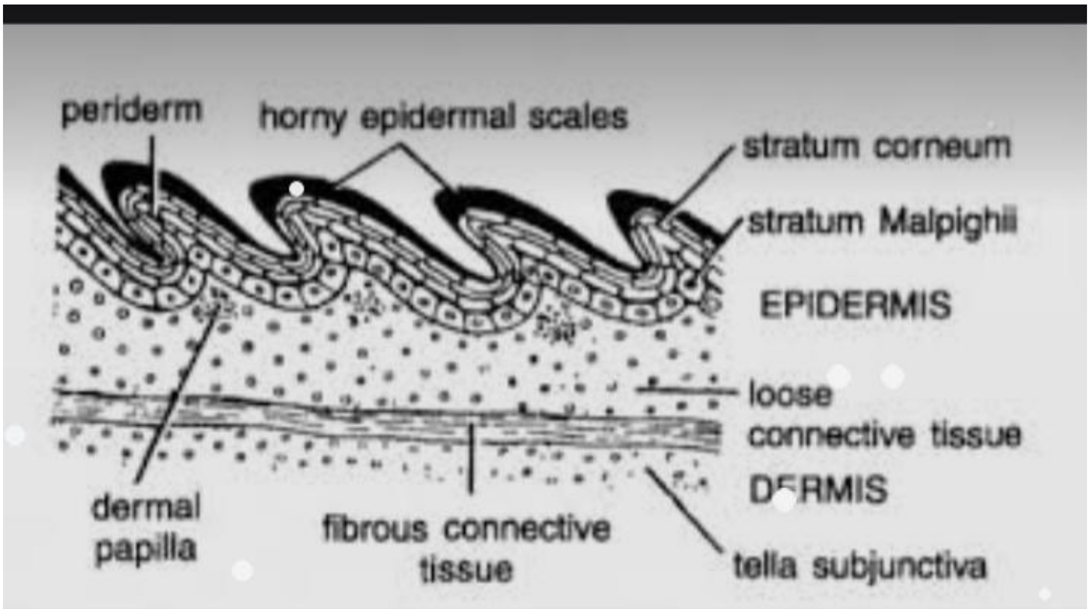
شكل ٤٥ ـ قطاع رأسى من جلد الضفدعة

FIG. 45 - V.S. OF THE SKIN OF THE TOAD



Dermal system of Reptilia

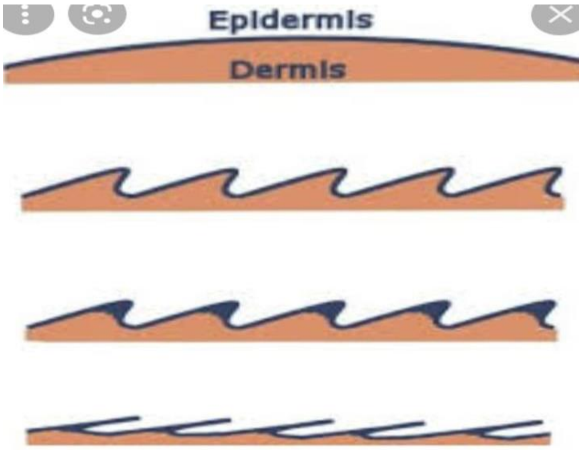
The skin of reptilia is dry due to the absence of glands, where they need to keep water in their body. The epidermis is very thin, consisting of two or three layers. The corneal layer of the epidermis is thick. The outer corneal layer is shed in lizards and snake in the process of ecdysis. The dermis is fibrous. The melanocytes may be found in the epidermis or below it in dermis. In all reptiles the skin is characteristically clothed by epidermal horny scales (cornusctus) bony dermal plates osteocutes are also found in turtels and crocodiles, but small one may be present in some lizards and snakes.

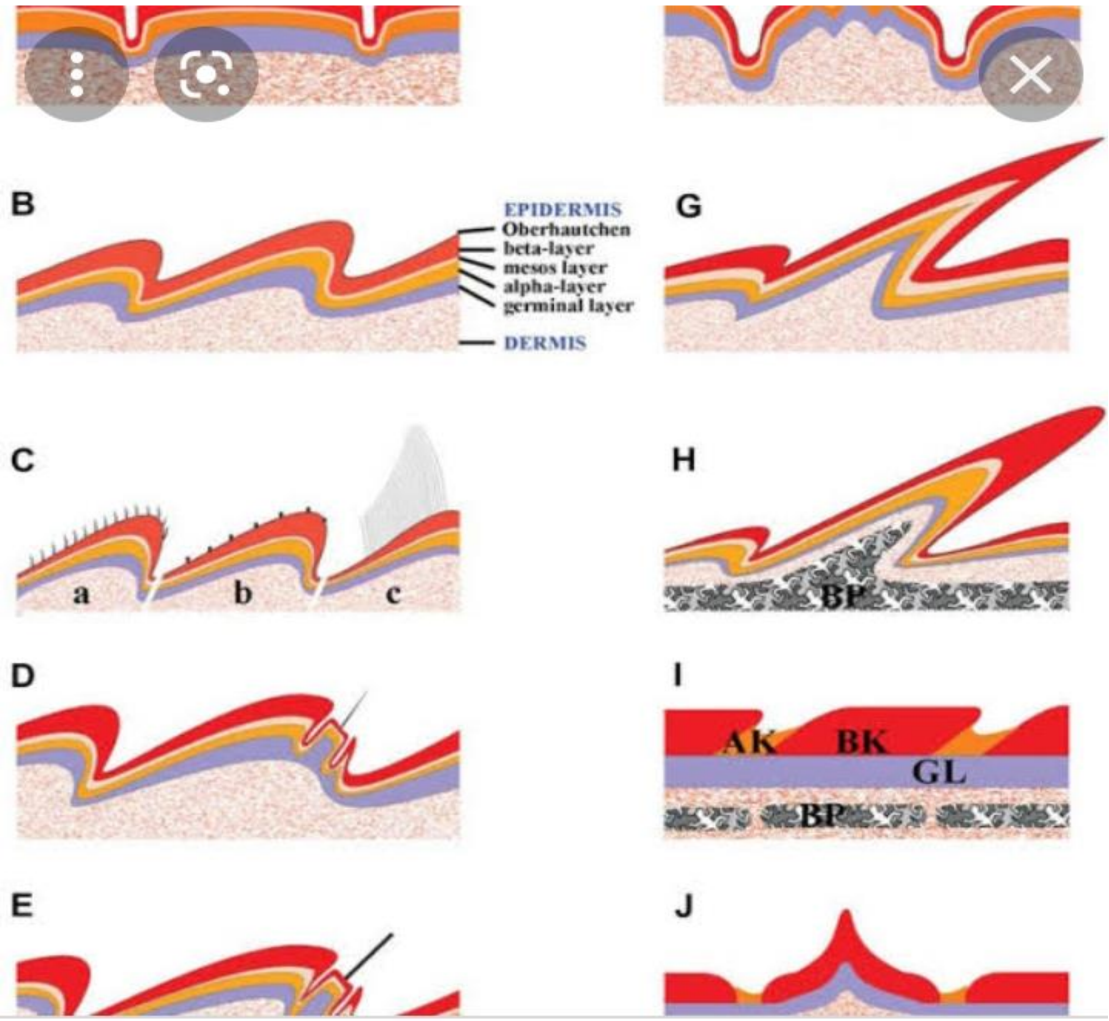


Development of horny scale in reptiles

By accumulation of the dermal cells forms dermal papillae, which supplies the str.Germ. Above with sufficient blood materials. The cells of str. Mucosum become compressed and flattened, as they become superficial.

They transformed into horny material by keratinization and give rise to the horny scale .The pulb of the epidermis is filled with connective tissue and becomes rich in blood vessels and nerves forming dermal papillae. The thick horny scales are connected together with a thin not cornified membrane called articulating membrane that aid in the movement of the animal.





Therefore, horny scale of reptilian are considered as thickened area of the stratum Cornium. There are not separated one another like those of fishes but they are thickened parts of continuous horny layer in the case of makes the whole layer covering the body is shed of at intervals as a single place and it replaced by new one, while in lizards it takes place by a small parts. This process is important for the growth of animal.

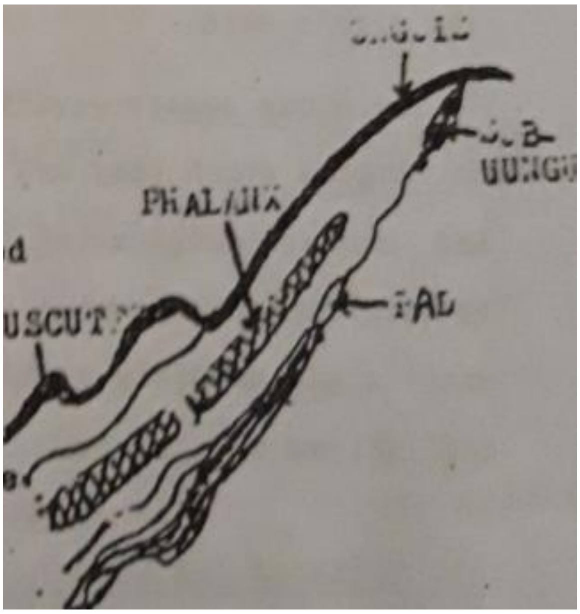
The bony plate (osteocutes)

This bony plates, are found in many reptiles, they are dermal in origin beneath the epidermal horny scales .sometimes small dermal plate are found among lizards, snakes and crocodiles.

In turtles there are what is known the bony shell. It consists of an arched carapace above and flattened plastron below and they united together by lateral bridges. Each structure composed of thin epidermal scutes (cornuscutes) to the outside and heavy large bony plates deposited in the dermis of dermal origin called osteocutes below. The bony plates of carapace are fused with the vertebrae and ribs. The osteocutes or the bony plates originate from dermal cells called osteoblasts which secrete the ostein (bony material).

The claws of Reptilia

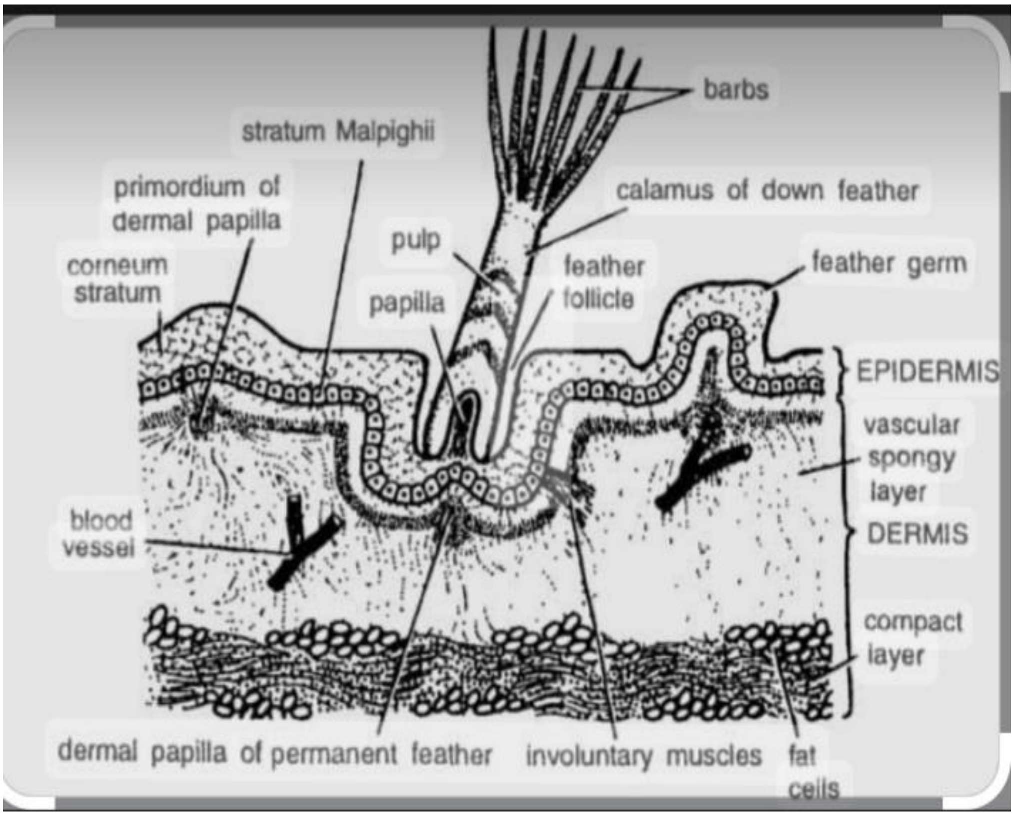
The claws are pointed and covered the last joint of the toe. It consists of dermal convex horny plate or scale known as the unguis which is terminal and covering the last phalanx of the digit and a concave subunguis. The junction between two plates often forms a sharp edge or angle, the origin of the skin following the claw, at its ventral surface remain formed the pod.


PHALANX
PAD

<u>**The dermal system of Aves (birds)**</u>

The skin of birds is more delicate than of reptiles. The epidermis is thin with highly cornified external surface. The dermis is fibrous the dermal melanocytes are usually absent but restricted to the feather follicles. The skin is characterized by absence of glands, except the two uropygial glands found at the base of tail of some birds which secrete oil which lubricating the feathers. The feathers on the greater part of the body which they are epidermal in origin constitute the exoskeletal derivatives of the bird skin.

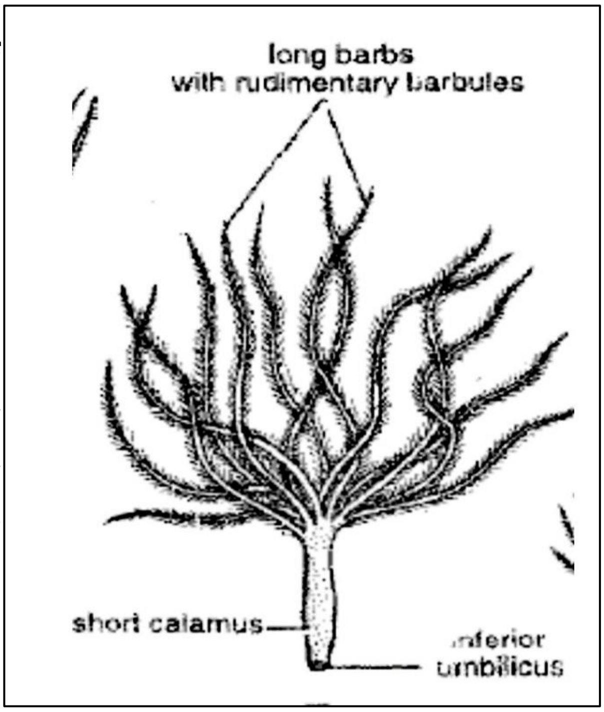
The horny scales covering the legs of birds, the claws of fingers which they are identical with those of reptiles and mammals originated from epidermal layer by cornification process and the horny beaks covering the maxilla and mandible of all birds skull are exoskeletal derivatives of epidermis in birds.



Types of feathers

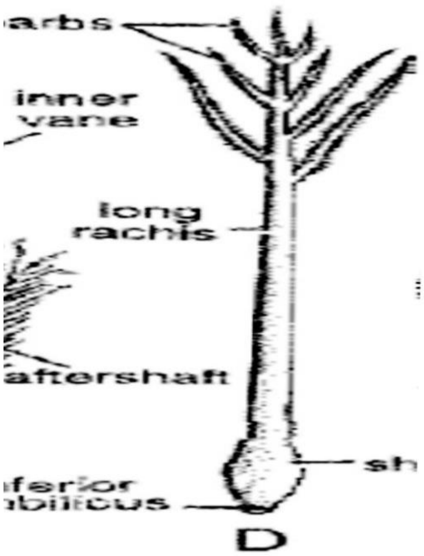
Feathers are found only in birds, they formed from beta keratin layer. In general there are four main types of feathers:

1: Down feathers (flumules): These feathers constitute the covering of young birds and occur in many of adults between the bases of contour feathers. They are shed when the contour feathers emerge later ,the down feathers consists of a short , thick, hollow stem or quill embedded in the instrument, and numerous soft rays or barbs arising in a circle from the top of the quill with minute side rayes or barbules along the edges of barbs Without booklets .



2: hair feathers (filoplumes):

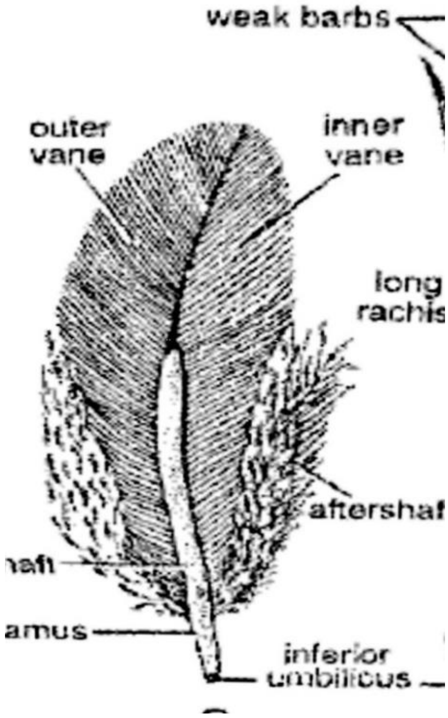
They are small and grow around the mouth and face and are usually scattered over the surface of the body, the hair feathers consists of a fine long axis carrying a few terminal (at its distal end) barbs separated from each other with few barbules and the latter are Without hooklets. The shaft is embedded in the skin and surrounded by the feather follicle at its base.



3: Contour feathers (plumes):

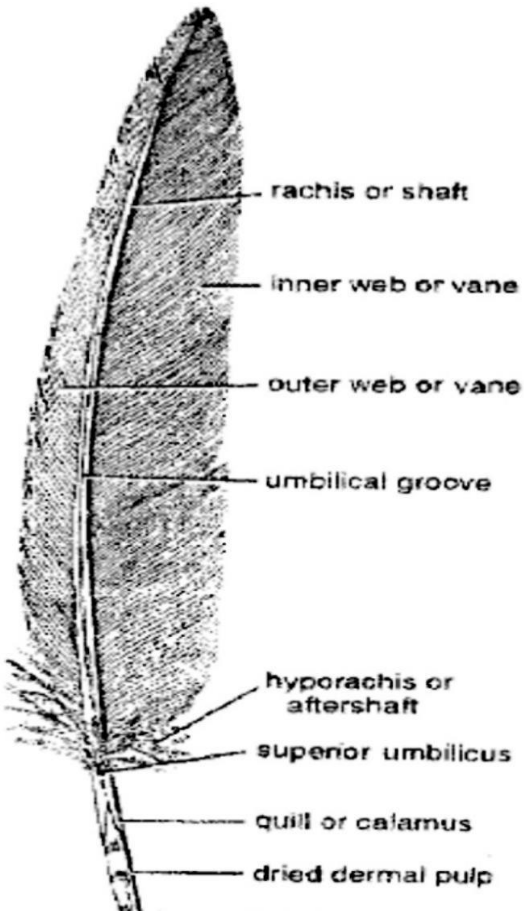
These feathers covered the whole of the body and give it the general outline or contour. They arise from certain areas of the skin called feather tracts or pterylae the contour feathers consists of a central axis that composes of basal quill and shaft or rachis , the shaft bear on each side the vane.

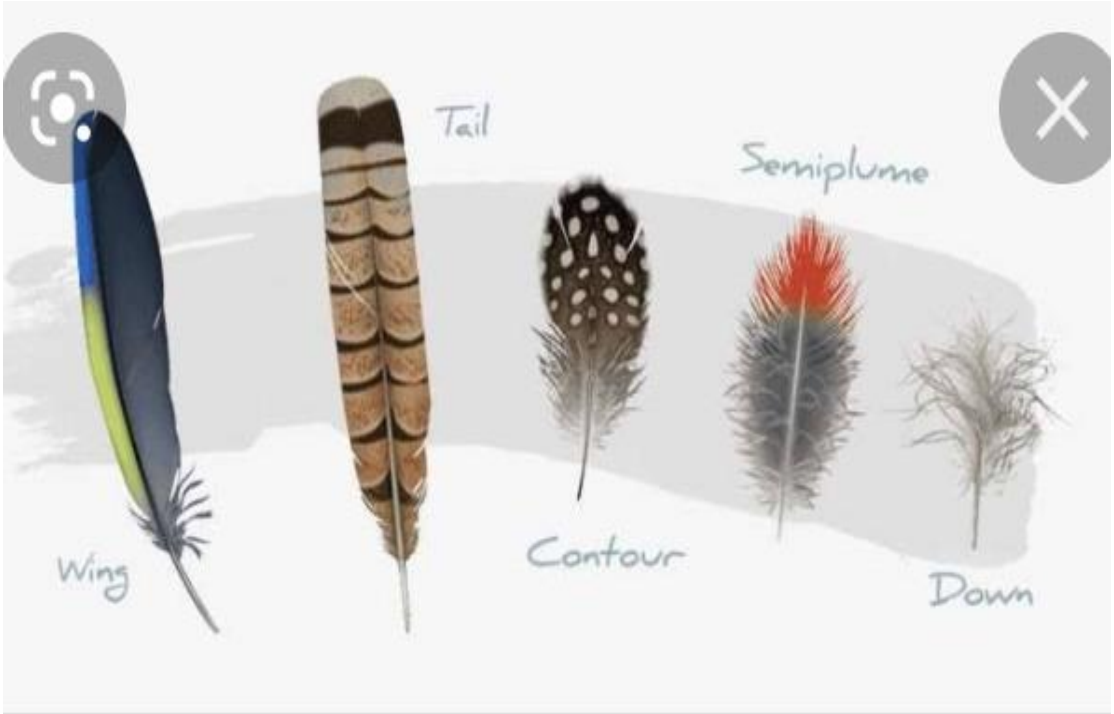
The inner part of the axis is pars and hollow. The quill has two opening inferior umblicus at the proximal end and the superior umblicus at the ventral side of the beginning of the vane. From the superior umblicus protudes accessory feather called the after shaft, consisting of only a few tufts in some birds and of a complete feather in other. The shaft has an umbilical groove on its ventral surface. The vane is composed of large number of parallel adhering oblique rays or barbs which carry barbules, the barbules. The barbules interlook through hooklets. In ostrich, all barbules lake hooklets and the whole feather is fluffy

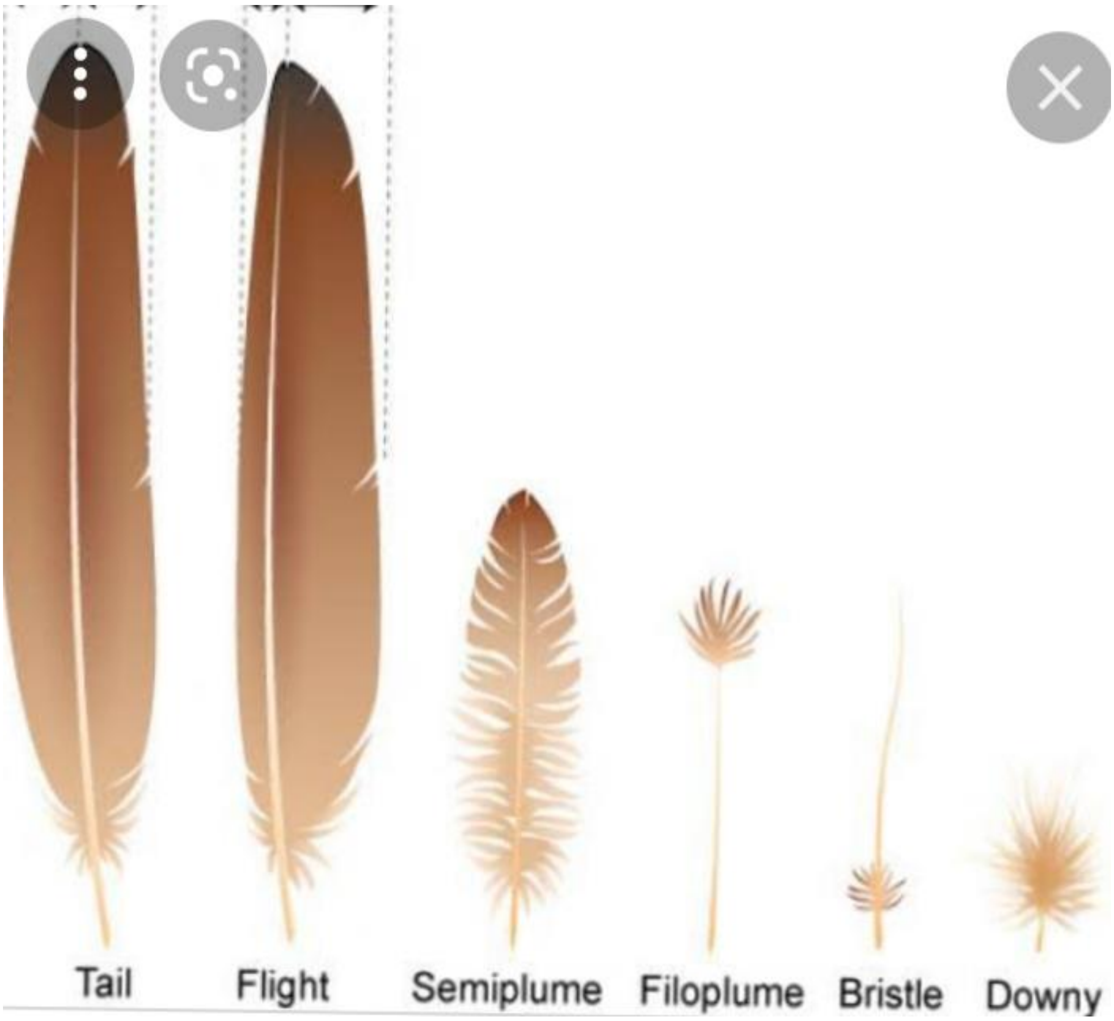


4- Quill feathers

These feathers are similar to the contour feathers but they are large and common type of wings which called the rings or flight feathers and in tail which called the rectrices or tail feathers. Molting is found among birds, where the feathers are shed periodically or seasonally and replaced by new one. The replacement takes place gradually.




Tail
Semiplume
Wing
Contour
Down


Tail
Flight
Semiplume
Filoplume
Bristle
Downy

The development of feathers of birds:

1. With accumulation of special mesenchymal cells appears in the dermis just below the epidermis and become covered by a cap of epidermis giving rise to the dermal papilla.
2. The papilla is supplied with blood from blood vessels of the dermal pulp, growth and lengthes with its epidermal

   Cap into a cylindrical cone, which projects above the surface, while its base deepens into a feather follicle (an annular groove appears around the base of the papilla).

3. The cells of str. Germ. Become active and divided continuously and due to this, more epidermal cells are formed and the epidermis becomes thick at this area. These cells press theoverlies cells and transformed into horny thin layer that forms the outermost layer of the developed feature which called the feature sheath or periderm (outer, thin cornified layer of the epidermis).

4 the cells of str. germ. (the epidermis beneath the sheath) proliferate upward to dorm a series of longitudinal ridges or columns of pigmented cells which project into the dermis and arrange on the surface of the dermal pulp into which they extend. Actually these ridges arise from a collar of cells (str. Germ. at the base of the papilla. The columns will be cornified and separate forming the barbs, and the stratum cornium of epidermis covering them becomes a definite thin sheath which surrounds a circle of barbs and still envelopes the feather.

5 New epidermal cells are modified also into pigmented columns to dorm the side branches of the barbs or barbules. The dermal papilla

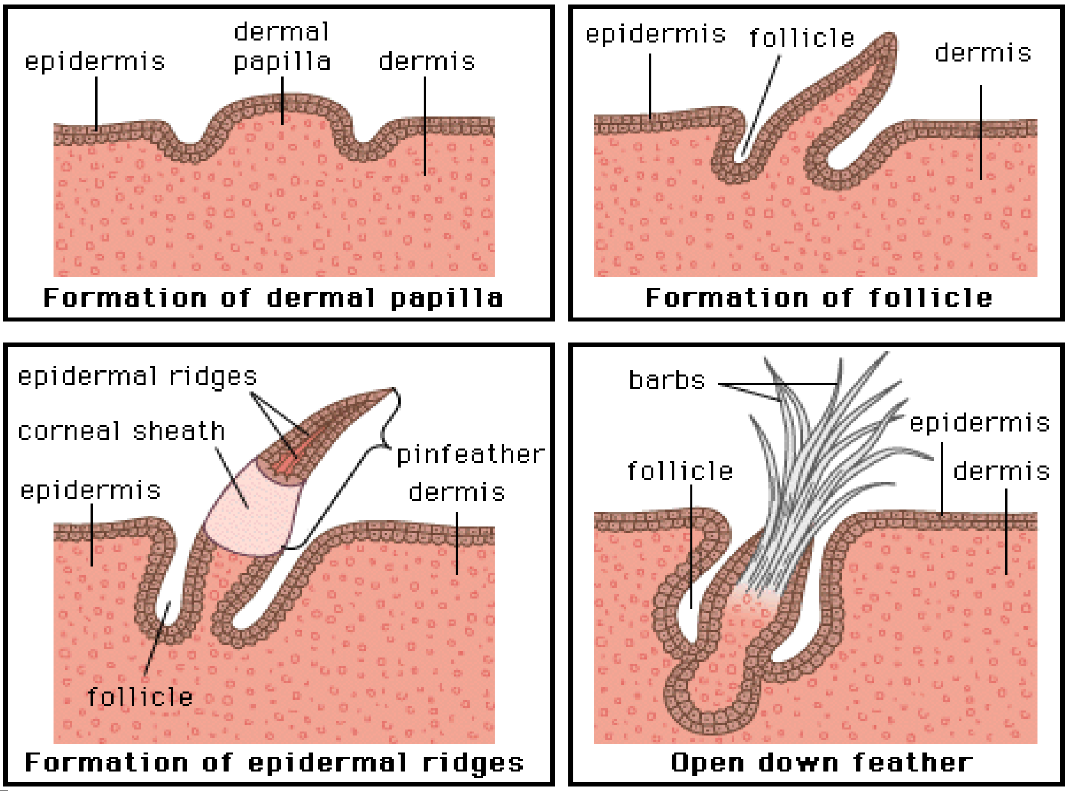
becomes connected and gradually retracts in the basal part of the growing feature, while its apical part is filled with connective tissue.

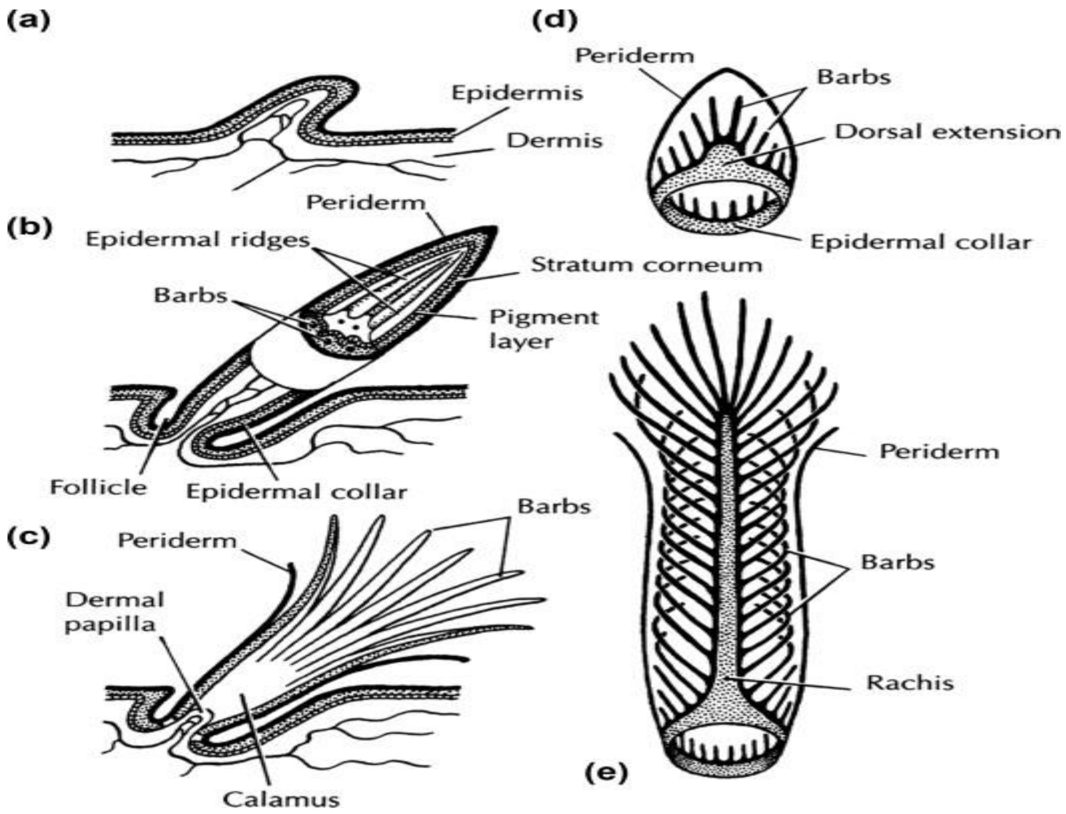
The entire structure is now called the feather gem. The feather germ with its sheath growth rapidly and soon projects from the feather follicle above the surface of the skin as a pin feather.

6 As the feather continues to grow, the proximal part of the ridges become cornified and separate from one another. The basal part of the future feather doesn't cornify into columns but produces a horny layer around itself, and encloses a pulp cavity within. This region gives rise to the quill of feather which doesn't split.

7 A small papilla remains at the base of the feather. This will give rise to another feather later on. If the feather developed into a Down feather, the sheath at its apex splits the tips of the ridges dry and the barbs release, which remain attached only to the top of the hollow quill.

If the feather develops into contour feather, the shaft Arises beyond the quill by exaggerated growth and Fusion of two ridges or columns (growth in one side of the collar of stratum germinativum at the base of the feather germ). Other ridges are drawn out along both sides of the shaft to form the barbs. When the sheath splits, the barbs Separate slightly, spread to form the flat vane and the pulp cavity of the quill dries into a hollow tube.


epidermis
dermal papilla
dermis
Formation of dermal papilla
epidermis
follicle
dermis
Formation of follicle
epidermal ridges
corneal sheath
epidermis
pinfeather
dermis
follicle
Formation of epidermal ridges
barbs
epidermis
follicle
dermis
Open down feather


(a)
Epidermis
Dermis
(b)
Periderm
Epidermal ridges
Barbs
Stratum corneum
Pigment layer
Follicle
Epidermal collar
(c)
Periderm
Barbs
Dermal papilla
Calamus
(d)
Periderm
Barbs
Dorsal extension
Epidermal collar
Periderm
Barbs
Rachis
(e)

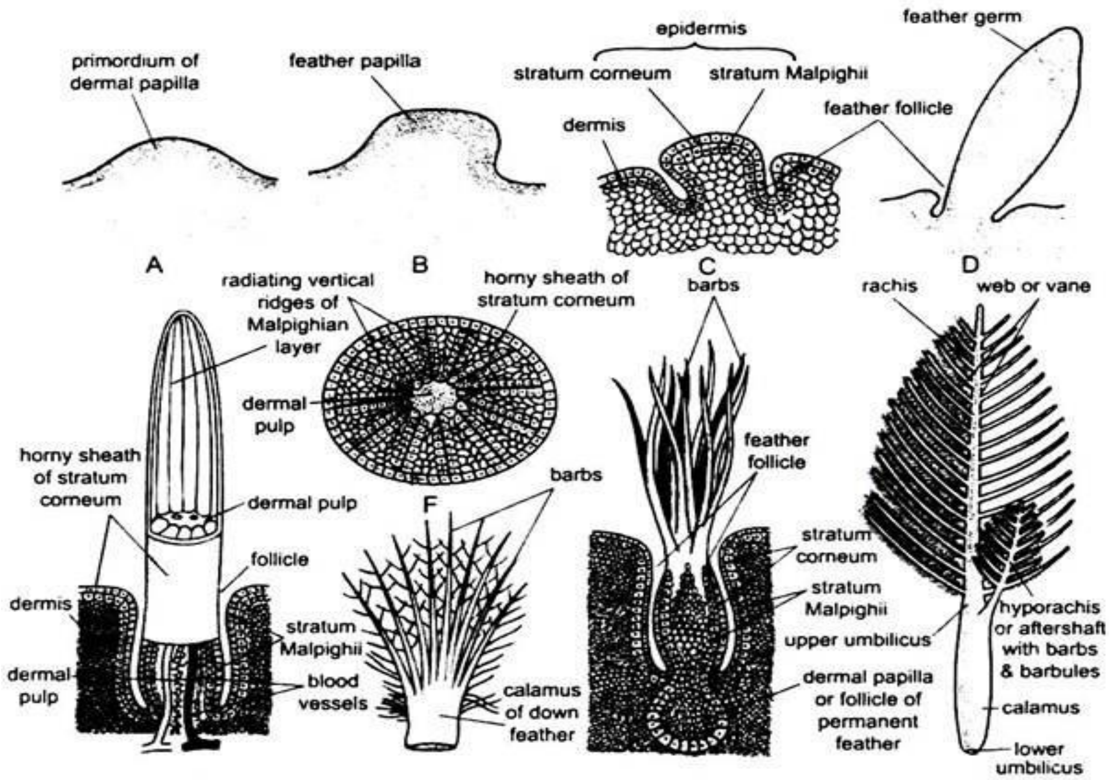
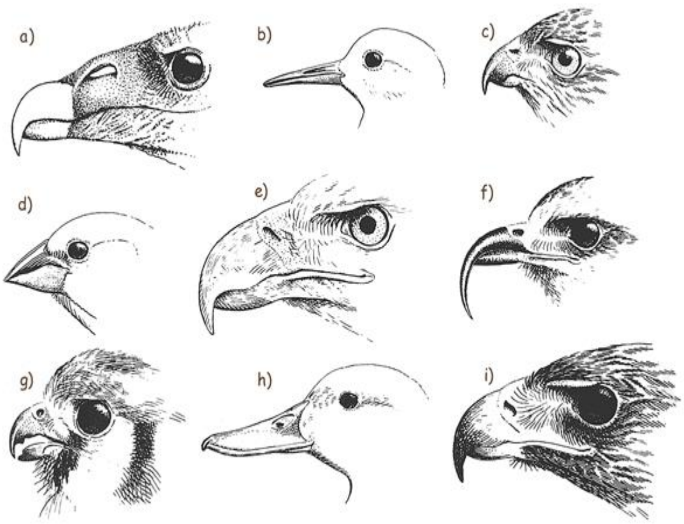


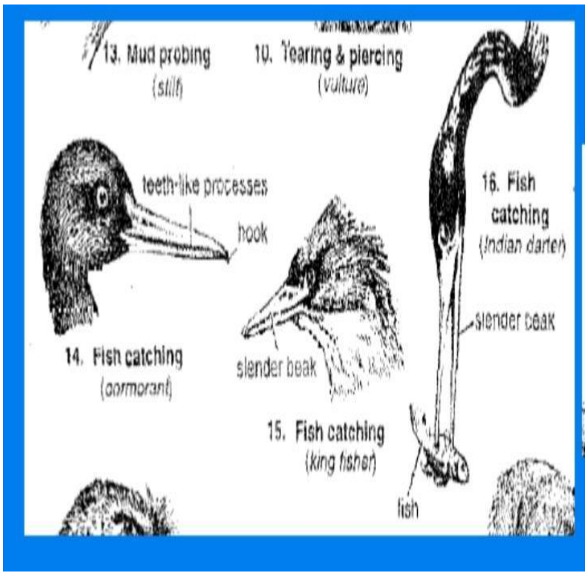
Fig. 26.10. Stages in the development of a contour feather. A–Beginning of feather papilla; B–Feather papilla arising above skin surface; C–Same in V.S; D–Feather germ; E–Feather germ in V.S; F–Feather germ in T.S; G–Down feather in its follicle; H–Mature down feather of a newly hatched bird; I–Young contour feather.

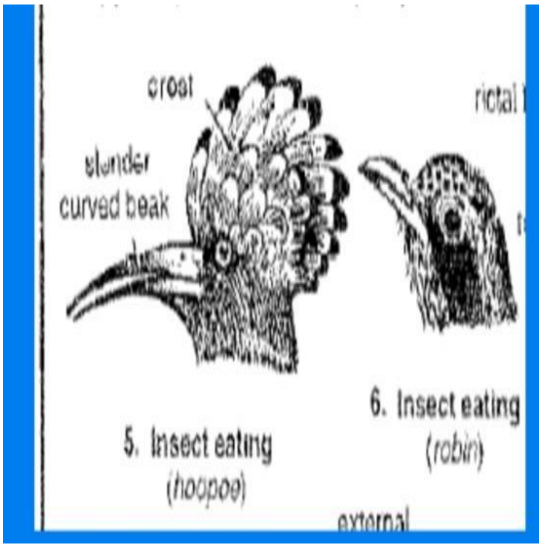
- **The horny beak of birds:**

The beak (bill) which covers the maxilla and mandible of birds is epidermal in origin. Correlation with its role in procuring food it differs in size and shape.

Seed eating birds usually have short, strong rather blunt beaks, while insect waters possess long, weak and narrow beaks. The long, strong hooked beaks of prey are will fitted for their methods of obtaining food.


a)
b)
c)
d)
e)
f)
g)
h)
i)


13. Mud probing
(stilt)
10. Tearing & piercing
(vulture)
teeth-like processes
hook
16. Fish
catching
(Indian darter)
slender beak
14. Fish catching
(cormorant)
slender beak
15. Fish catching
(king fisher)
fish


crest
slender
curved beak
5. Insect eating
(hoopoe)
6. Insect eating
(robin)
external

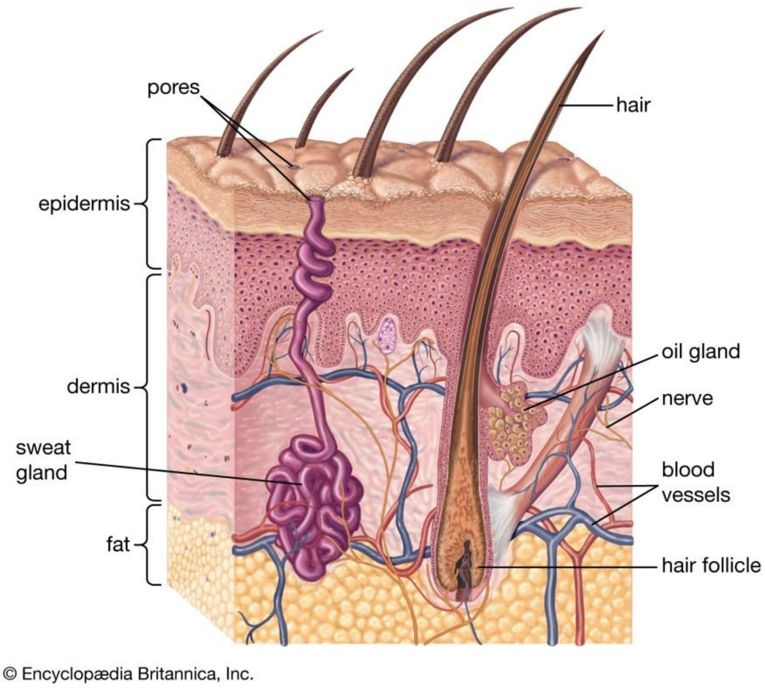
- **The dermal system of mammalia:**

The epidermis is very thick in the regions of the body which come in contact with the external objects such as the sole of foot and the palm of hand, where the stratum germinativum is thick, and the corneal layer is granular, hyaline, and very thick.

The dermis is thicker in proportion to the epidermis than in other vertebrates. It composes melanocytes are found in mammalian skin between the epidermal cells, sometimes they are found in the dermis.

Below the dermis is a fatty layer, which is thicker in some regions than in others. The sub cutaneous fats of whale are an adaptation to life in the icy season.

The exoskeletal derviatives of the mammalian skin are the multicellular epidermal glands, hairs, nails, horns and hoofs which they are epidermal in origin



- **Types of mammalian glands:**

There are two essential types of glands from which all glands are probably derived, sweat glands and sebaceous glands.

1. Sweat glands: The glands are either simple coild tubular or simple branched tubular glands, arise as invaginations of the epidermis into the dermis and open in the surface of the skin. These glands secrete the sweat as a cooling device important in thermal regulation and removal of salt, urea and other waste products.

2. Sebaceous glands: The gland is alveolar, opens into the hair follicle and secrets a fatty or oily substances for lubricating the stratum cornium. They may open directly on the surface of skin of some areas. They are absent from the palms and soles as well as from the skin of marine animals (Cetaceans).

They are found in the corner of the mouth and lips, internal surface of labia minora, mammary papilla and occasionally on the glands penis.

3. Scent glands: Many mammals possess scent glands. They are either modified sweat glands or sebaceous glands. They may be useful in attracting members of the same species or the opposite sex. In some they serve in attracting prospective food items, in others they function as a defence against enemies. These glands are located in the region of the eyes (Deer), near the anal opening (carnivores), open into the rectum just inside the anus (weasels), at the openings of the reproductive organs (rodents), on the face (some bats), between the hoofs (pigs), or over the temporal bone (elephant) and in still other mammals on the arms, legs and other parts of the body.

4. Mammary glands: The milk producing glands, present in all mammals and only in mammals, are actually modified sweat glands. These glands are multitubulated and arise in both sexes from a pair of elevated ribbons of ectodermal cells called milk lines, extending along the ventrolateral body wall of the fetus. Along the milk lines develop patches undifferentiated mammary tissues, which invade the dermis and spread under it. Nipples develop above each patch. They are active only at certain times immediately before the young are born and generally as long as active sucking continues.

In prototheria (Monotremes), the mammary glands are primitive and open in depression on the abdomen and they are functional in in both parents. The milk oozes over hairs and the young mammals grasp tufts of hair and obtain their nourishment by lapping .

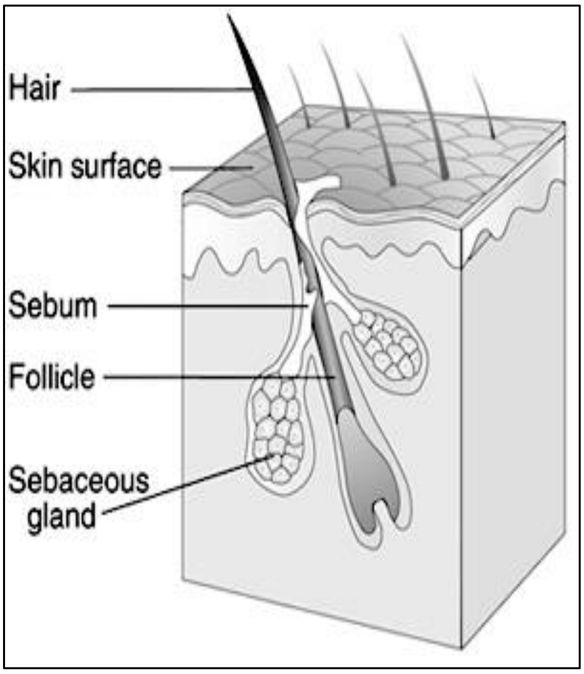
In Metatheria and Eutheria, the mammary glands are functional in the females only. They open in the surface through nipples or teats. The nipples or teats are grasped by mouth of the young when sucking.

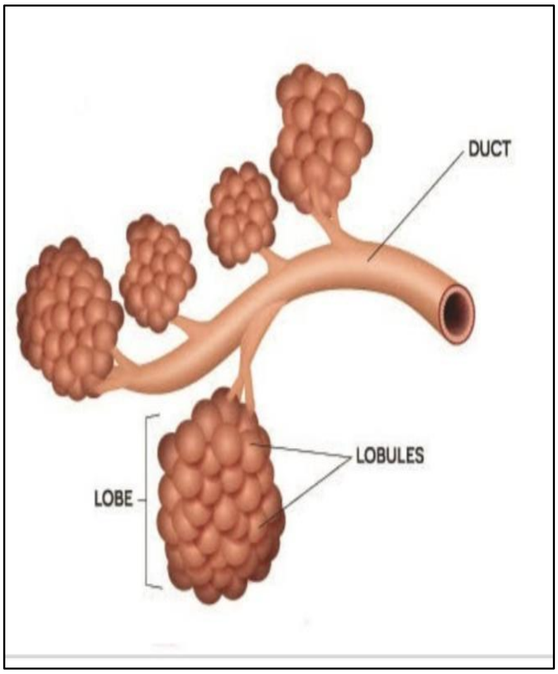
A nipple is a raised area on the breast through which the mammary duct or ducts open directly to the outside on the top of the nipples. In the false nipple or teat, present in horses, cattle and others, the skin of mammary area grows outward to dorm a large projection and the ducts collect the milk in a reservoir called the cistern, from each a large secondary canal drains the cistern milk to the top of the teat.

Generally they vary from 1 pair in the man to 11 pairs in certain insectivorees. In man, bat's, horses, whales and elephants there are only two nipples or teats, so since these animals give birth to one or two youngs.

In the case of animals which give birth to many youngs such as pigs, dogs and edentates, there are many of them.

The mammary glands lie in two ventrolareral rows in dogs, cats and pigs, between the hind legs in horses and cows, between the front legs in elephants or in the pectoral region in primates.

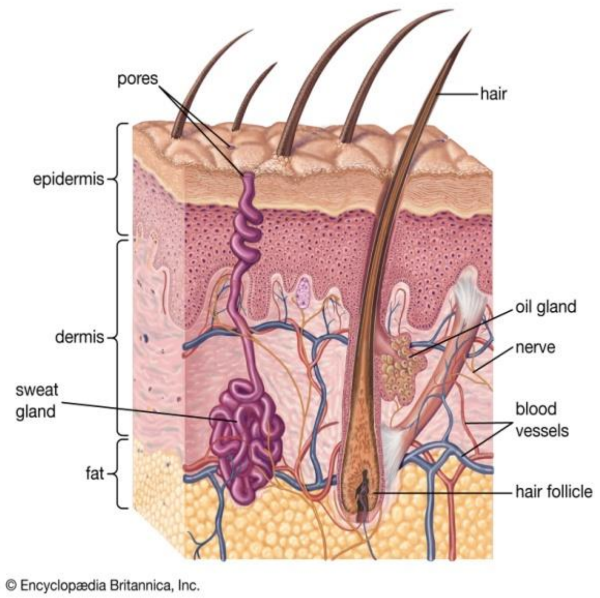

Hair
Skin surface
Sebum
Follicle
Sebaceous gland

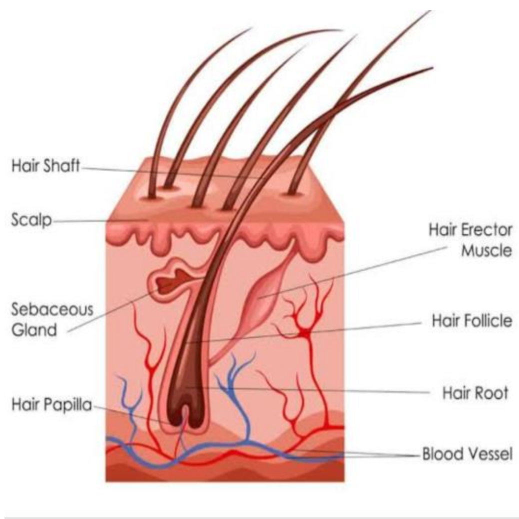

DUCT
LOBULES
LOBE

The structure of hair

Hairs are cornified modifications and they may be shed seasonally. At the base of the follicle, the hair is expanded slightly to form a bulb - like enlargment, the root of the hair. All growth takes place at the root, where the cells of str. Germ. are proliferating. Beyond this point the cells gradually die, the shaft of the hair thus being composed of dead, cornified cells. The shaft lies free within the hair follicle and projects above the surface of the skin. It's composed of three layers, a central core, the medulla, a middle cortex and an outer covering cuticle of dead keratinized (alpha keratin) cells. The medulla within the hair is composed of air space and dermal elements, and covered by a layer of elongated cells, the cortex and enveloped by the outer layer, the cuticle. Color of the hair when present, is due to the color of pigment which located in the intracellular space in the cortex or in the medulla or in both or due to the amount of air in the intracellular space of the medulla. The root of the hair is the deep portion with the follicle, it's cell become cornified and dried. The bulb is a swelling part at the base of the hair and contains the dermal papilla, it's cells are contributed to the lengthing of the hair by mitotic division. The hairs grow from the hair follicles that projecting deep into the dermis.

The density of hair on the body on the body shows much variation in different mammals. Those living in cold climates have have the heaviest coats of all. Tropical forms are often sparsely covered. A permanent living in water is associated with an almost total absence of hair in cetaceans and sierenians. White hair is due not to the prescence of white pigment but to lack of all pigment, light being reflected in all directions from air spaces, particularly those in the medulla. The sensory tactile hairs present on the snout of the nocturnal mammals such as cats and rats (vibrissae), the protection strong hairs the eyelides (eyelashes), the spine of Hedgehog , the very large hairs on the tail of angulates the dust arresting hairs in the nose of man are modified hairs in mammals. The follicles of these sensory or modified hairs have and a bundant nerve and blood supply at their bases.





- **The development of hair in mammals :**

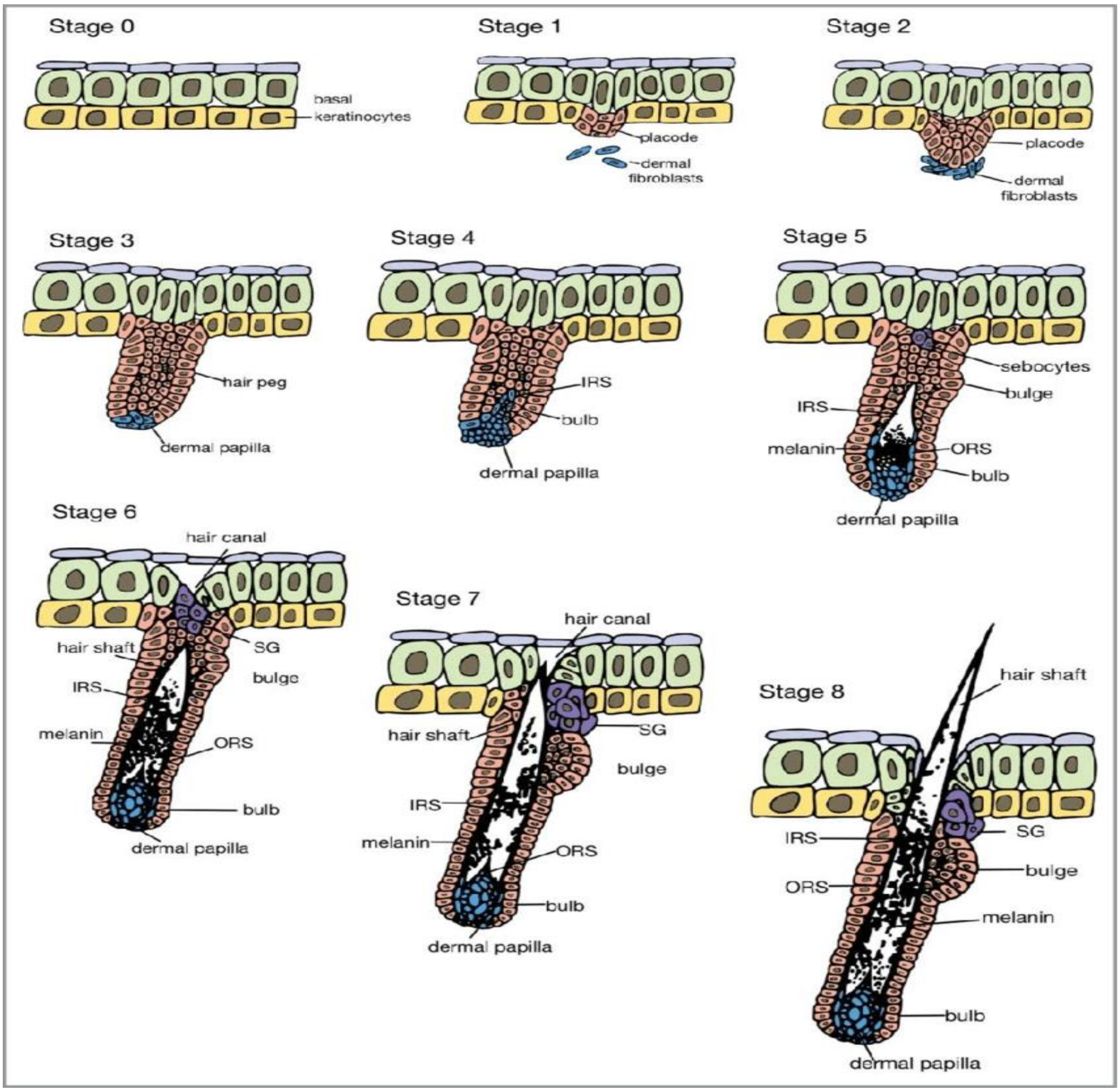
1. The cells of str. germ. At the region where the hair will be developed become active and begin to proliferate and invaginate towards the dermis forming a thickened cylindrical hair follicle. Special special mesenchymal cells or dermal papilla organize just beneath the epidermal invagination.

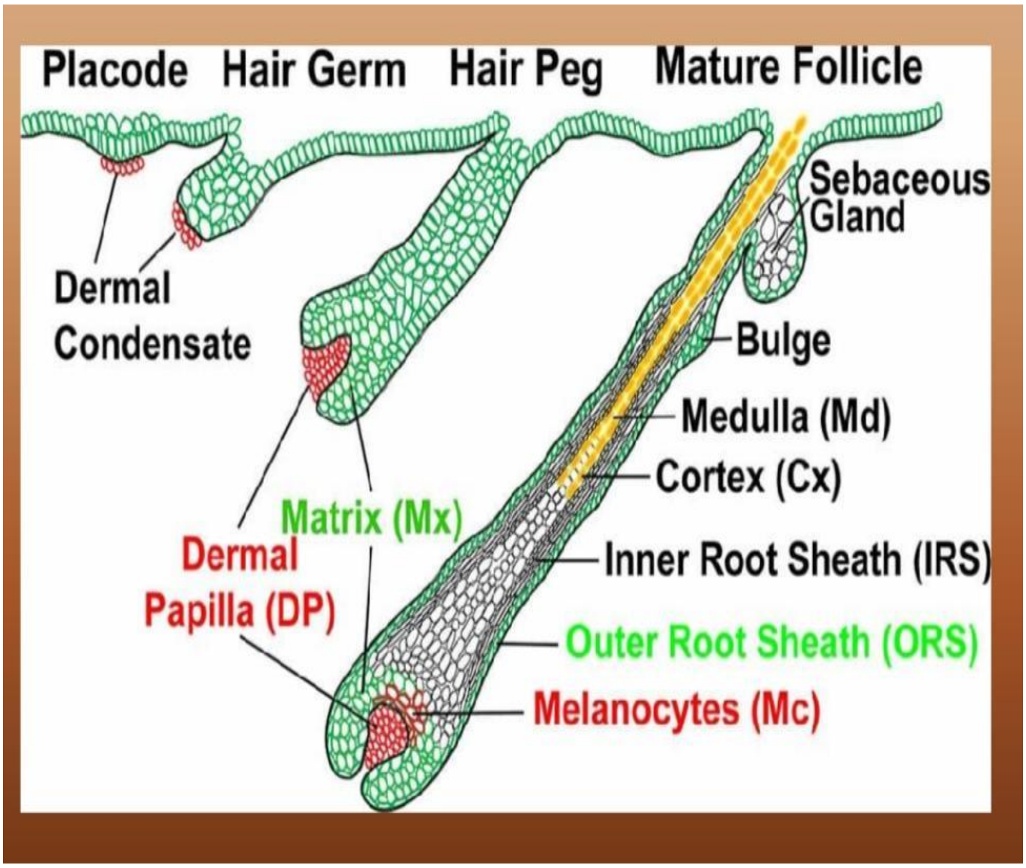
2. The invagination of the str. germ. Is followed by other epidermal cells forming the so called the hair germ. This hair germ becomes gradually more deep and the mesenchymal cells increase in number due to their activity.
3. The mesenchymal cells press upon the ventral or the inner border of the hair germ, thus forming a bulb shaped structure known as the hair bulb. (i. e the hair germ makes a cap over the papilla). The mesenchymal cells and the connective tissue inside thin bulb form the hair (dermal) papilla that nourishment the developing hair.
4. The cells of the hair germ (stratum germinativum) are activated and proliferatd giving rise to a small conical mass of cells from which the hair rudiment or periderm developes. This mass of cells at the central part of the hair germ undergoes keratinization at its terminal part forming the hair proper.
5. During the development, the hair germ becomes more deeply embedded in the dermis and with continuous proliferation; the hair grows deeper into the dermis giving rise to the hair root.
6. Then the bulb at the base of the hair is differentiated, cornified cells commence to make their appearance, and hair shaft begins to rise out of the follicle. The hair cone within the hair follicle or as a result of keratinization, the follicle gives rise to a central hair shaft and an inner hair sheath.

The hair continuous to be pushed out from below until it pierces the surface of the skin and becomes visible from outside. At the same time sheaths of the hair roots become formed: The lining of the follicle (close to the hair proper) is called the inner root sheath. It is somewhat cornified and dirfarentiated in the adult stage into an outer Henle's layer and an inner Huxley's layer. It is the white coat that clings to the roots of the hair when they are pulled off. The outer root sheath extends as far the str. germ.

The new formed hairs develop either from new hair follicles as normal or from epithelial bed outgrowths of the down or fine hairs of the embryo which they represent reserve epithelial materials for future or adult hair generation. If there is complete destruction of the str. germ. and papilla regeneration of hair will not occur. If a hair is pulled out, the place where it gives is usually Just above the str. Germ. at the base of the follicle.

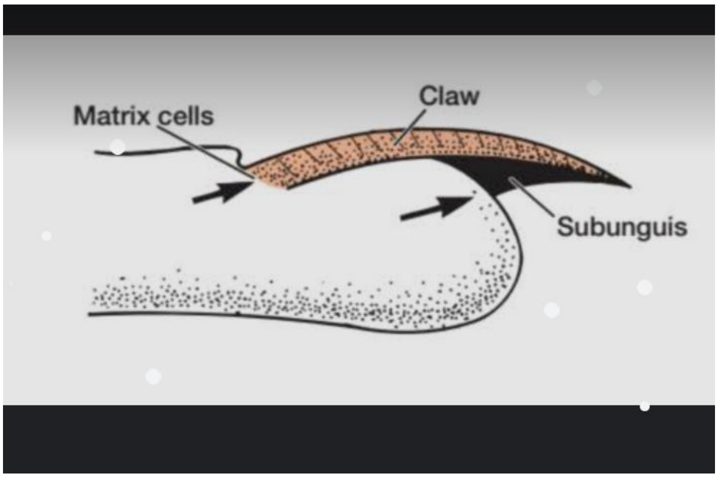
A new hair then usually grows in its place. Hairs which grow to a considerable length before they loosen and are shed (head hair of man) are said to be angora. Definitive hairs, on the other hand, grow to a certain length and then stop. They are then shed and quickly replaced (eye lashes, eye browes and body hairs). Angora hairs may persist for several years, but definitive hairs usually last only a few months.


Stage 0
basal
keratinocytes
Stage 1
placode
dermal
fibroblasts
Stage 2
placode
dermal
fibroblasts
Stage 3
hair peg
dermal papilla
Stage 4
IRS
bulb
dermal papilla
Stage 5
sebocytes
bulge
IRS
melanin
ORS
bulb
dermal papilla
Stage 6
hair canal
hair shaft
SG
bulge
IRS
melanin
ORS
bulb
dermal papilla
Stage 7
hair canal
hair shaft
SG
bulge
IRS
melanin
ORS
bulb
dermal papilla
Stage 8
hair shaft
IRS
SG
bulge
ORS
melanin
bulb
dermal papilla



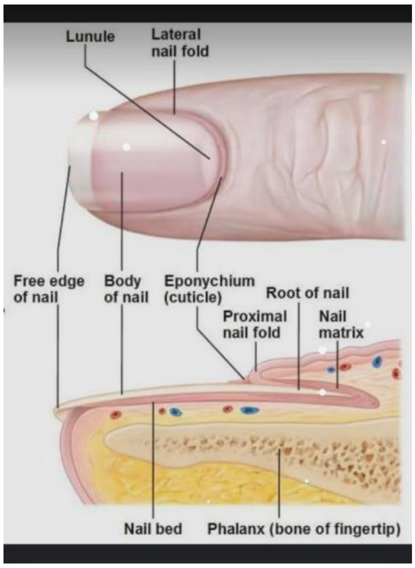
The Claws of Mammals:

The claws of some mammals develop as in the case of reptile claws. The claw consists of dorsal unguis and ventral sub unguis. The claw covers the terminal phalanx of the digit. Cat has retractile claws which when not in use are withdrawn into a sheath.



The nails of primates and human:

The nails are found at the ends of fingers. It consists of a broad flattened unguis, the subunguis is usually reduced or absent and lies under the tip of the nail.



The Hoofs of ungulata:

Hoofs are found on the top of the digits. It consists of unique which surrounds the front of the toe and a subungius which is greatly enlarged and thickened and covered the ventral side or the toe. Since the unguis is of harding consistency than the subunguis, it wears away more slowly And a rather sharp edge is thus maintained

The horns of Mammals:

The horns of mammals are structures of different origin and composition. Horns of Rhinoceros are median and made up of long epidermal strands of keratin. These called the keratin fiber horns. The indian rhinoceros has one horn and the African two, one behind the other and the larger one being the more anterior. In cattle, Sheep and Goats, the horns are a hollow kiratin sheaths covering the hollow bony cores which are outgrowths of the frontal bones of the skull (hollow horns of both males and females). The horns are permanent and unbranched. they continue to growth from the str. germ. between it and the bony core. Horns are present in both sexes, but there are sexual differences in its size and shape.

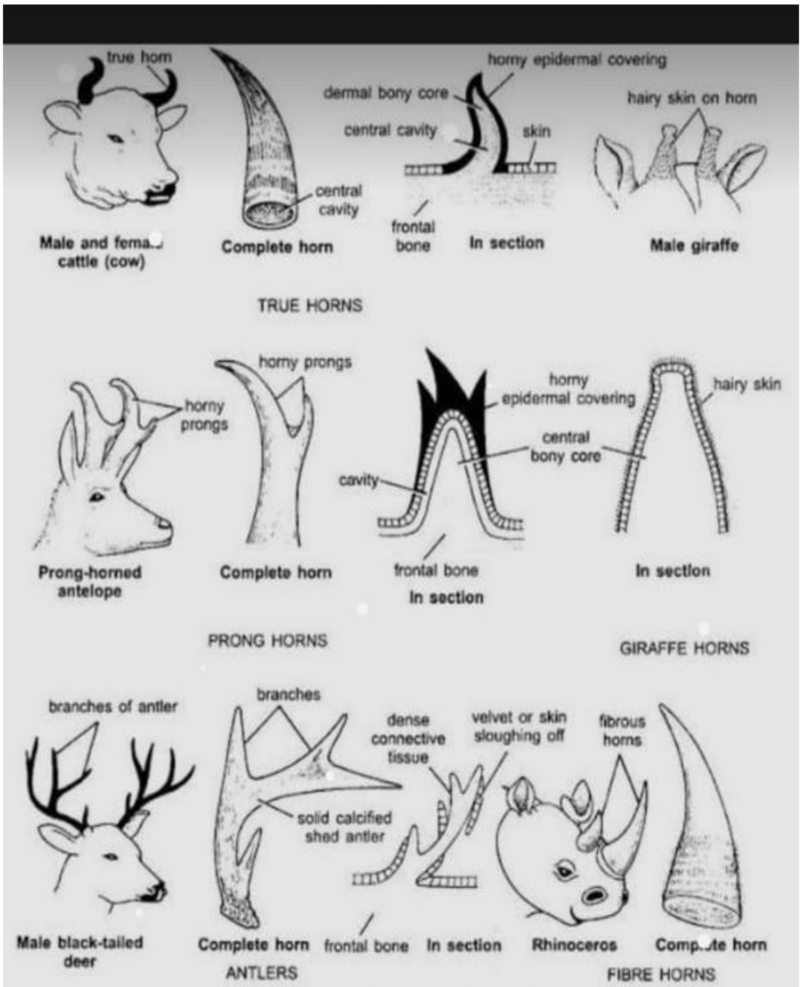
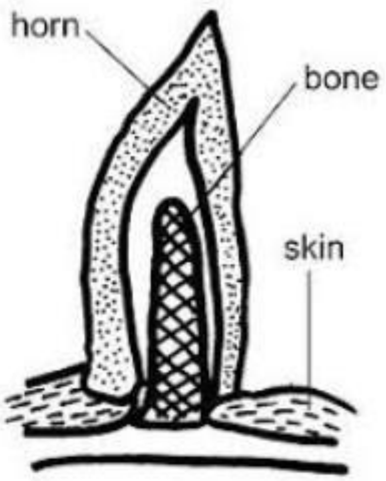


Fig. 41.4. Types of mammalian horns and antlers.



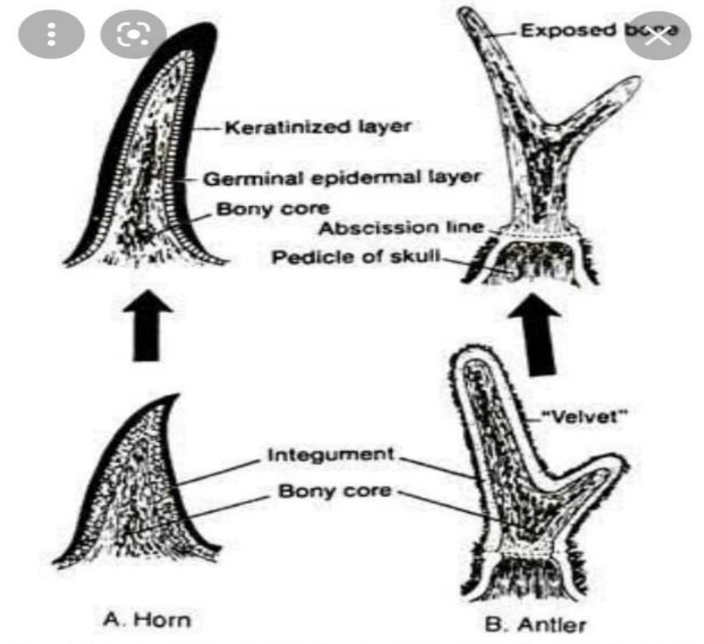


Fig. 2.21 : A. Horns and B. Antlers. Showing early and developed stages

<u>The True Teeth of Mammal:</u>

Teeth are primarily embloyed by animals in cutting grinding, or crushing food but may in addition, serve structures used in attack of defense, The true teeth are homologous with the placoid scales of cartilagenous fishes in their development from epidermis and dermis. The portion of the tooth that is exposed and called the crown is covered with enamel, under this lies the somewhat softer dentine, composed of calcified connective tissue. The dentine surrounds a pulp cavity filled with soft connective tissue and supplies with a call nerves and blood vessels. In mammals a layer of cementum forms around the root of the tooth. At the tip of the root is a small opening through which nerves and blood vessels enter the pulp cavity.

<u>Among lower vertebrates</u>, teeth rest on the surface of bone or cartilage and are not inserted in sockets. Such teeth are early lost and replaced by new ones developing below.

- Sharks have sharp conical teeth replacing placoid scales. These teeth can be replaced by moving up of the back rows.

- Most bony fishes have conical teeth, found in a single row or several rows or in patches and vary greatly in shape and arrangement, some bony fishes lack teeth.

- Among Amphibia, Apoda and Salamanders have two rows of teeth in the upper jaw and in the lower. Most frogs have a single row of small teeth in the upper jaw and none in the lower one. Toads are toothless.

- In Reptilia, squamata have palatal and marginal teeth a bove. Poisonous fangs are found in certain snakes as in Vipera. Chelonia have no teeth. The teeth are uniform shape in which all teeth of reptiles are similar or homodont type.

- Birds have no teeth although teeth are found in the ancestral forms such as archaeopteryx.

-Among mammals, monotremes are toothless. Marsupials have about 50 teeth as in Opossum and this is an primitive number.

Placental mammals such as Pig and horse have started with 44 teeth and becoming heterodont 44 $\frac{3-1-4-3}{3-1-4-3}$

in advanced types of mammals such as apes and humans, the number is reduced, becoming 32 teeth, its dental formula 32

$$\frac{2-1-2-3}{2-1-2-3}$$

Rodents have lost the more lateral incisors, the canines and more anterior premolars, having a wide gap called the diastema.

between the single enlarged pair of incisors and the sheek teeth(premolars and molars). The dental formula of rat 16

$$\frac{1-0-0-3}{1-0-0-3}$$

In herbivorous, incisors are modified or lost.

Ruminants such as cows and sheep have lost the upper incisors but retain the lower ones, sheep 32

$$\frac{0-0-3-3}{3-1-3-3}$$

Carnivorous animals such as Cats and Dogs have relatively small incisors and possess the so called carnassial teeth.

These teeth are the last premolar in the upper jaw and the first molar in the lower jaw, where they are very large and sharp and differ from other premolars and molars. These carnassial teeth act together as grinding surfaces. The teeth in front of carnassial teeth are compressed and pointed, while the teeth behind them have grinding surfaces. Canines are best developed in carnivorous animals. The dental formula of cat 30

$$\frac{3-1-3-1}{3-1-2-1}$$

of dog 42

$$\frac{3-1-4-2}{3-1-4-3}$$

The incisors of Rabbit have characteristic chisel snaps and they are rootless and grow out through the whole life, and there are no canines, therefore a diastema is present between incisors and premolars. The dental formula of Rabbit 28

$$\frac{2-0-3-3}{1-0-2-3}$$

D.F (dental formula)=

$$\frac{number\ of\ teeth\ on\ the\ half\ of\ the\ upper\ jaw}{number\ of\ teeth\ on\ the\ half\ of\ the\ lower\ jaw}$$

Dentition in vertebrates

. **Homodont**: In vertebrates other than mammals, all the teeth present are similar in shape and size.

2. **Heterodont**: Mammalian teeth are characteristically *heterodont,* that is, dissimilar in shape and size. They are distinguished into several types known as *incisors, canines, premolars* and *molars.* This differentiation depends upon the nature of food eaten

[II] Attachment of teeth

1. **Acrodont**: This condition occurs in most vertebrates in which teeth are attached to the free surface or summit of the jaw bone, as in a shark or frog. Such teeth are break off easily but are replaced.

2. **Pleurodont**: In this condition, common in lizards, teeth are attached to the inner side of jaw bone by their base as well as one side.

Acrodont and pleurodont teeth are rootless, so that nerves and blood vessels enter the pulp cavity along lateral side.

3. **Thecodont**: Such teeth are characteristic of mammals. Teeth have well developed root simplanted in deep individual pits or sockets in the jaw bone

Mammalia : General Account

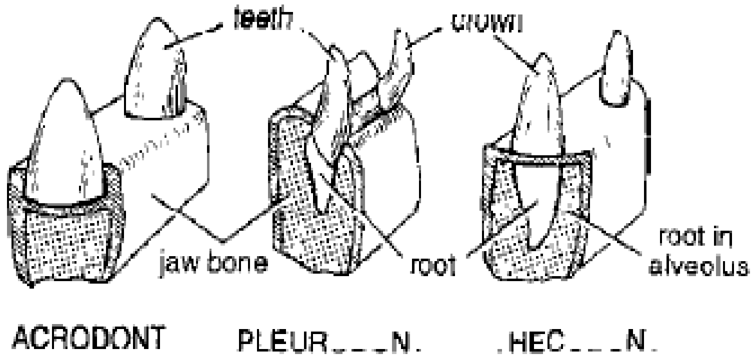


Fig. 1. Three methods of attachment of teeth to jaws.

surface or summit of the jaw bone, as in a shark or frog. Such teeth are apt to break off easily but

[III] (Replacement) of teeth

According to their replacement, teeth fall into 3 categories:

polyphyodont, diphyodont and monophyodont.

1. **Polyphyodont** In lower vertebrates, teeth can be replaced an indefinite number of times during life.

2. **Diphyodont** In most mammals teeth develop during life in two successive sets, a condition known as diphyodont. Teeth of the first set are called milk teeth. As in human

3. **Monophyodont**. In some mammals such as some rodents, only one set of teeth develops, known as monophyodont condition.

Endoskeleton system

The vertebrate endoskeleton consists of ligaments, cartilage and bones, there are two kinds of bones: cartilage or replacing bones which replace the cartilaginous stage and membrane or covering bones which arise from the mesenchyme directly without passing in the cartilaginous stage and formed over the replacing bones. Both kinds of these bones are histologically the some, but they differ in their mode of formation.

The skeleton is divided into axial and appendicular parts. The axial skeleton consists of the skull, the vertebral column, ribs and sternum, while the appendicular skeleton consists of the limb bones and limb girdles.

The Skull:

The skull is the most complex part of the axial skeleton which found in the head region surrounding the brain and the sense organs. It comprises two main parts, the cranium or the neurocranium (brain-case) with the sense capsules such as the olfactory, optic and auditory capsules, and the splanchnocranium or the visceral skeleton which is composed of the gill arches and the upper and lower jaws, hyoid arch, ear bones and the cartilage of the larynx.

The skull originates in its early development in the embryos of vertebrates from the condensation of mesenchymal cells at certain centers which transformed gradually into cartilaginous cells forming the first type of skull called the chondrocranium. This type remains cartilaginous throughout the whole life in Cyclostomes and Cartilagenous fishes. In vertebrates above cartilagenous fishes (advanced vertebrates) the cartilage cells in the chodrocranium become replaced during further development, partly through classification of these cells into osteoblasts, replacing or cartilaginous bones to give rise to second type of skulls namely the osteocranium and partly through the addition of new bones called the dermal or membrane bones without passing into cartilagenous cells forming the third type of skulls known as the dermatocranium.

In cyclostomes such as petromyzon, the brain case forms a floor and side walls around the brain. There is no roof except a narrow occipital arch.

In the form of petromyzon, the skull is developed from two pairs of rods called the parachordals: a pair of anterior parachordals on the sides of the anterior end of the notochord and a pair of Posterior ones behind them and near the otic or the auditory capsules.

The parachordals and the otic capsules fuse together making an incomplete floor and side walls for the brain. Aanteriorly a single nasal or olfactory capsules appears and posteriorly small pieces of cartilage arise between the gill pouches, forming the visceral cartilages (7 visceral arches).

In Gnathostomes, the two jaws are first appear from the first visceral arch. This arch seems to migrate forwards above and below the mouth to form the upper (platoquadrate) and lower (mandible or meckel's cartilage) jaws on each side of the skull. The second visceral arch give rise to the hyoid arch and the remaining five arches constitute the gill arches which support the gill slites.

The skull in the elasmobranch fishes remains cartilagenous and its roof is also not complete and it possesses e large opening known as the anterior fontanella which it is closed by connective tissue. The side walls of the skull are perforated by small pores for the passage of nerves and blood vessels, the upper jaw carries a movable articulation with the cranium (hyostylic suspension).

Development of the chondrocranium:

There are differences in the details of the development of chondrocranium among different groups of vertebrates. However, the development follow main steps in the embryos of all vertebrates.

Three pairs centers of chondrification which derived from the mesenchymal cells of the head mesoderm and lie close to the notochord developed. These accumulation centers of cells are gradually transformed into elongate cartilage elements a pair on both sides of the anterior end of the notochord called the parachordals, a par anterior to these underlying the anterior end of the brain known as trabeculae or prechordals and sometimes a pair of small polar cartilages forms between the parachordals and trabiculae (prechordals).

At the same time, cartilagenous sense capsules appear around the sense organs, these are the olfactory, the optic and the otic or auditory capsules which surrounded the nose, the eye and the ear respectively. Then the occipital arch appears at the posterior end of the parachordals. During the development fusion between these three pair elements takes place. Posteriorly, the parachordals fuse together medially forming a basal plate, which enclosed the notochord and extends laterally to unit with the auditory capsules. Usually, the anterior ends of the parachordals become connected by a transverse bar called the acrochordal cartilage leaving an opening behind (anterior to the notochord) known as the basicranial fenestra.

Anteriorly, the trabiculae and the polar cartilages if present fuse to each other and fuse with the parachordals. The trabiculae fuse together anteriorly forming an intertrabecular or ethmoid plate and leaving a hypophyseal fenestra behind (between the ethmoid plate and acrochordal to the blood vessels, the intertrabecular plate don't reach the optic capsules in the eye region, therefore the optic capsules remain free, thus allowing free movement of the eyes.

The intertrabecular plate, however extends anteriorly to reach the olfactory capsules and fuses with them. Anteriorly it gives rise to a main prolongation between the nasal capsules called the internal septum.

If the trabeculae are widely separated and hence a large hypo-physeal fenestra exists, a primitive platybasic skull is formed without an interorbital septum, as found in lower fishes and amphibians and if the trabeculae are closely placed and there is a skull hypo-physeal fenestra and interorbital septum, this skull is called tropibasic skull, as found in higher fishes and most tetrapodes.

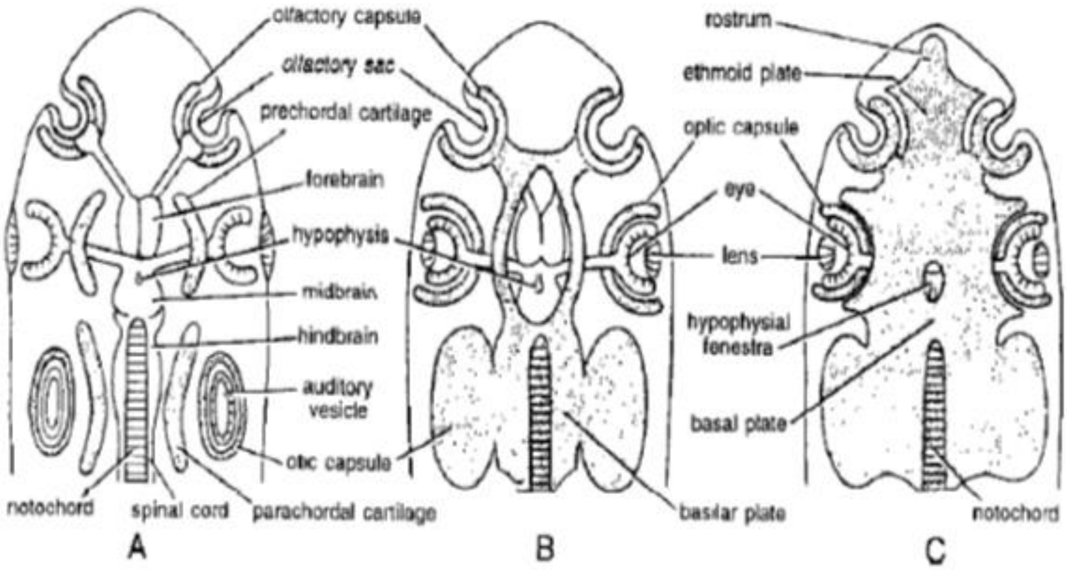
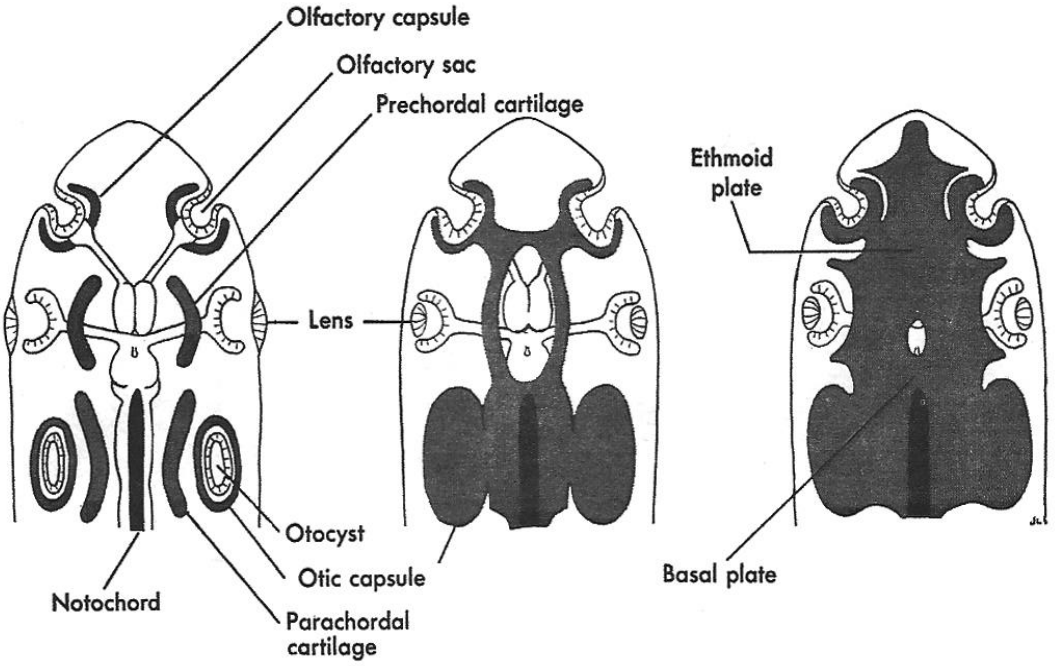
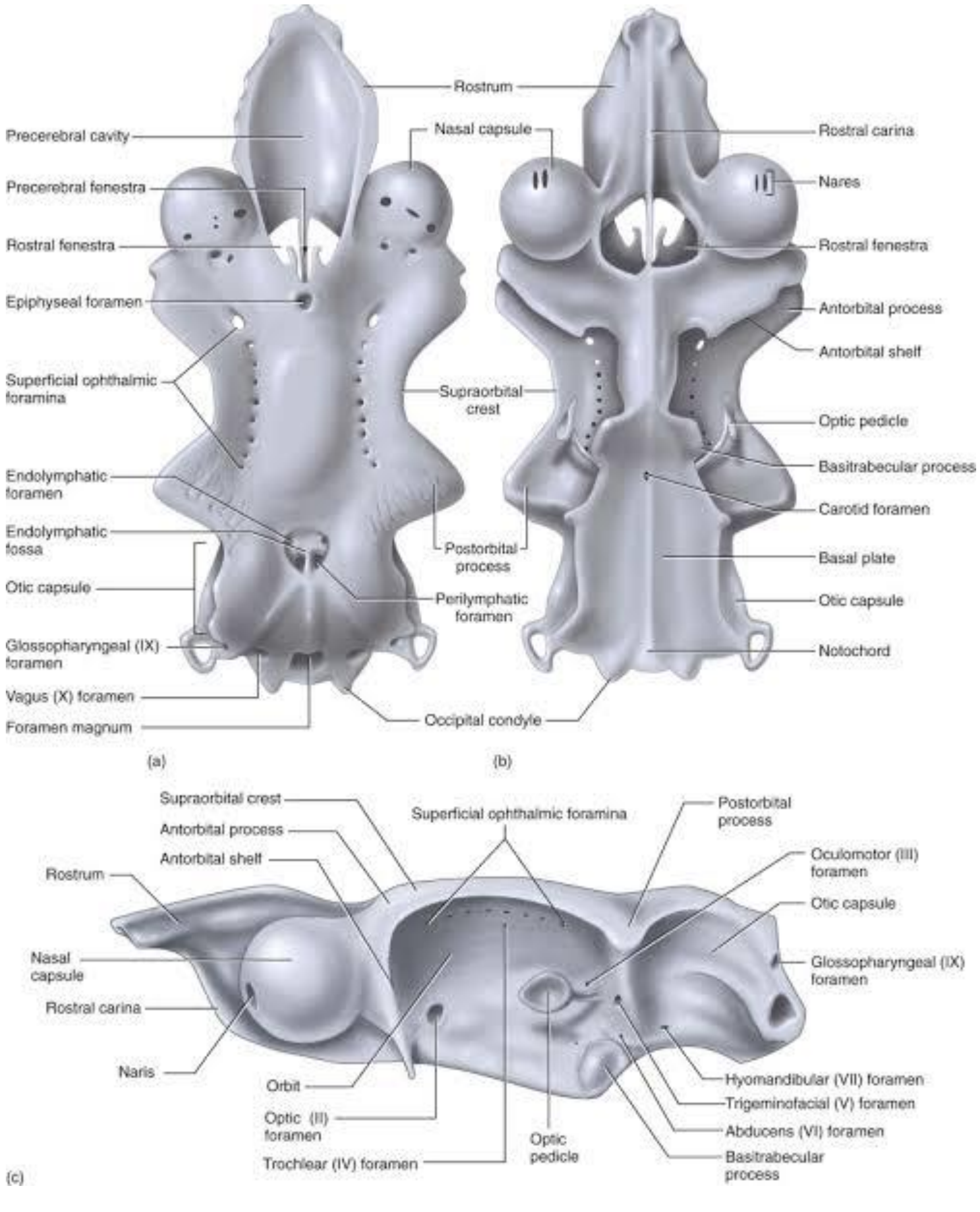


Fig. 1. Stages to show diagrammatic development of chondrocranium or cartilaginous neurocranium in ventral view A—Cartilages appear in head of embryo B—Formation of ethmoid and basilar plates. C—Chondrocranium completed


Olfactory capsule
Olfactory sac
Prechordal cartilage
Lens
Otocyst
Otic capsule
Notochord
Parachordal cartilage
Ethmoid plate
Basal plate



Rostrum
Precerebral cavity
Nasal capsule
Rostral carina
Precerebral fenestra
Nares
Rostral fenestra
Rostral fenestra
Epiphyseal foramen
Antorbital process
Antorbital shelf
Superficial ophthalmic foramina
Supraorbital crest
Optic pedicle
Basitrabecular process
Endolymphatic foramen
Carotid foramen
Endolymphatic fossa
Postorbital process
Basal plate
Otic capsule
Perilymphatic foramen
Otic capsule
Glossopharyngeal (IX) foramen
Notochord
Vagus (X) foramen
Occipital condyle
Foramen magnum
(a)
(b)
Supraorbital crest
Superficial ophthalmic foramina
Postorbital process
Antorbital process
Antorbital shelf
Oculomotor (III) foramen
Rostrum
Otic capsule
Nasal capsule
Glossopharyngeal (IX) foramen
Rostral carina
Naris
Hyomandibular (VII) foramen
Orbit
Trigeminofacial (V) foramen
Optic (II) foramen
Abducens (VI) foramen
Optic pedicle
Basitrabecular process
Trochlear (IV) foramen
(c)

B) The side walls of the chondrocranium:

The auditory capsules form the side walls of the posterior part of the chondrocranium. In the eye region, two separate plates of cartilage which are formed from accumulation of mesenchymal cell between each eye and the corresponding side of the brain give rise to the orbital cartilages. These chondrified materials appear independently and then fused ventrally with the polar cartilages and trabeculae, and posteriorly with the auditory capsules, leaving some foramina or fenestrae for the passage of cranial nerves and blood vessels from and to the brain.

Lateral to the orbital cartilage are developed another independently cartilages called the supra orbital which forms the roof of the orbit and protects the eye dorsally and the suborbital which constitutes the floor of the orbit and protects also the eye ventrally. The orbital cartilage is also fused with the auditory capsule of each side forming what is known as the postorbital process.

C) The roof of the chondrocranium:

After the formation of the floor and the side walls of the chondrocranium, the roof begins to be formed as follow:

Posteriorly, in the region of the auditory capsules, two cartilage plates grow also from the dorsal edges of the otic capsules towards the middle line, and fuse together to form a complete roof, known as a tectum synoticum.

In the orbital region, two plates of cartilage grow from the orbital cartilages and extend medially to form a complete roof for the brain in the eye regions called the dorsalis cranil.

In the olfactory region, however no roof is found and a large cup called the anterior fontanelle is left between the two olfactory capsules.

D) The occipital arch:

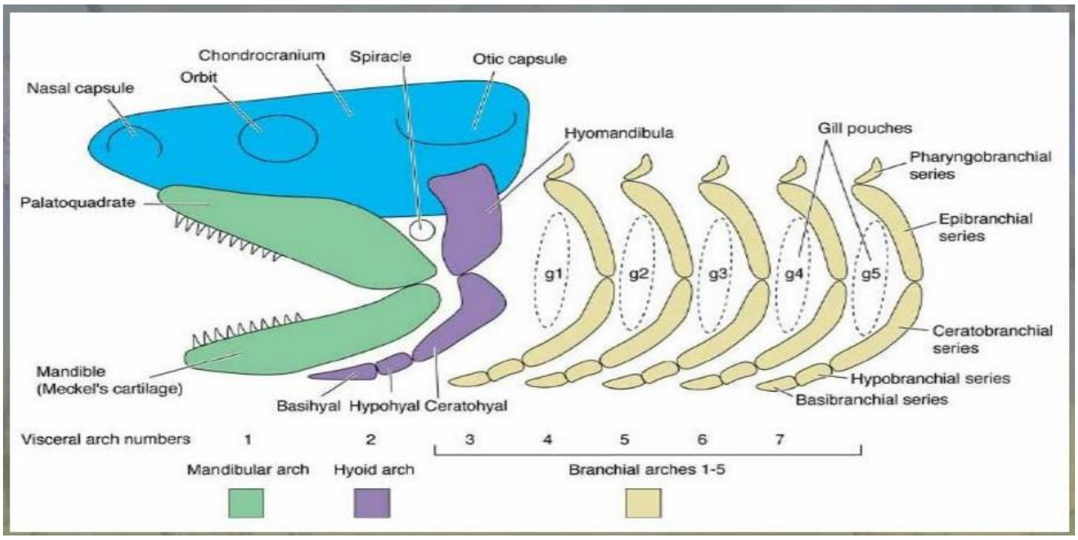
Posterior to the otic capsules, the region of the parachordals is segmented in nature. The segments in this region form upward projections of both sides. The last segment may be called occipital arch and segments in front are preocoipital arches.

Certain vertebrae may be added from behind, and these are called occipitospinal arches, and from some of these arches a roof develop above. The preoccipital, occipital and occipito spinal arches, together with their roof and the tectum synoticum perform the occipital arch of the adult skull, bounding a large foramen magnum through which the spinal cord passes.

E) The visceral arches or the splanchnocranium:

The visceral skeleton supports the gills and consists of a number of cartilagenous pairs, developing in the splanchnic mesoderm between the gill slites. In the dog fish there are only seven pairs or arches. The first pair is called the mandibular arch and give the platoquadrate (the upper jaw) dorsaly and a ventral meckel's cartilage (the lower jaw). The platoquadrate grow foreward them the upper of anterior margin of mouth and unite together in the middle. The meckel's cartilages are also extended along the lower part of the posterior margin of mouth and unite in the midle line.

The second arch is called the hyoid arch that plays an important part in the jaw suspension, the remaining arches (3-7) are known as the gill arches.



There are different ways of jaw suspensions to the crnaium in Gnathostomes:

1-Amphistylic jaw suspension as in primitive elasmobranches:

The platoquadrate is provided with a well developes otic process which takes a certain part in jaw suspension . it also articulates with the postorbital process. In the addition to this, the jaws are also connected with the skull by hyomandibular cartilage of the hyoid arch . the cartilage is attached to the cranium and lower jaw by ligaments.

2-Hyostylic jaw suspension as in most elasmobranches and in all teleostomes:

The platoquadrate has no otic process and its posterior part is far away from the auditory capsule. The jaws are suspended by the hyomadibular cartilage which is well developed and attached to the otic region

3-Autostylic jaw suspension as in most vertebrates:

The platoquadrate articulates to the chondrocranium with processes. The hyomandibular takes no part in jaw suspension. Therefore, it is either very weak developed or it is completely absent in some forms. The palatoquadrate may be suspended by four processes:

1-ethmoidal process from the anterior end of the platoquadrate and fused with the ethmoid region of the skull as in fishes and amphibia.

2-ascending process is found in dipnoi and tetrapodes and becomes the epipterygoid bone, basal process articulates with process from the chondrocranium and found in elasmobranches, Dipnoi, primitive teleostomes and tetrapodes, and otic process attatches with the otic region and becomes the quadrate bone in tetrapodes.

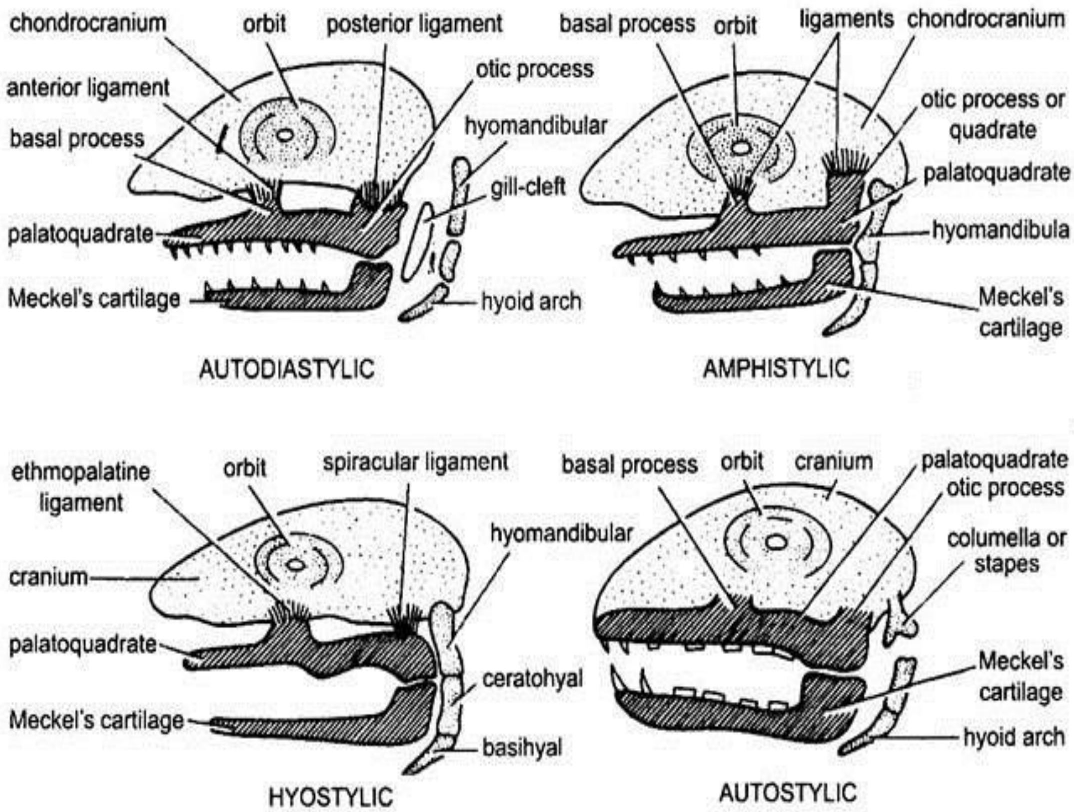


Fig. 42.7. Types of jaw suspensoria in vertebrates.

Development of the osteocranium:

In all vertebrates above cartilagenous fishes the skull is called osteocranium. After the formation of a well formed chondrocranium , the cartilage cells gradually transformed into osteoblasts or bone cells. Such transformation results in the formation of the cartilage bones or replacing bones that developed in the region of give rise to osteocranium.

Replacing or cartilage bones on the tetrapode skull:

Replacing bones are formed in certain regions of ossification from chondrocranium which can followed in rings from the posterior to anterior. Cartilage bones arise also in the madibular and hyoid arches.

1) Replacing bones in cranium:

a-Occipital bones or occipital ring:

In the occipital region of skull, four bones ossify and surround the foramen magnum, these are :

Supraoccipital, it is a single bone present above the foramen and arises from ossification of the tectum synoticum.

Basioccipital, it is also a single bone found below the foramen magnum and arised from the ossification of the posterior part of the parachordal plate.

Exoccipitals, these bones are two bones on both sides of the foramen magnum and formed by ossification of the occipital arch.

In modern Amphibia, the occipital ring is reduced being formed from only the exoccipitals and there are neither a supraoccipitals nor a basioccipital which were found in extinct amphibians.

A processes appear in the occipital region called the occipitals condyles by which the skull articulates with the first vertebra or atlas vertebra of the vertebral column.

In fishes, reptiles and birds there is a single occipital condyle, but in modern amphibians and mammls there are two accipital condyles .

b-sphenoid bones or schenoid ring:

Anterior to the occipital region, an ossification in the anterior part of the parachordal plate gives rise to the unpaired basisphenoid bone.

Ossification of the trabicular plate gives rise to presphenoid bone which is also single bone.

In the orbital cartilage region an ossification posteriorly forms the laterosphenoid bone and an ossification anterioly gives rise to the orbitosphenoid bone.

c-Ethmoid bones or Ethmoid ring:

Ossification of the internasal septum in front of the presphenoid leads to the formation of a mesthmoid bone. In mammls this bone extends vertically to form a complecated poly extension known as turbinals. In modern amphibia, a single ossification takes place in the orbitosphenoid region known as sphenethmoid bone. this leads to correspond to the presphenoid and the paired orbitosphenoids of mammals.

2) Replacing bones in the sense capsules:

a-otic or auditory capsules:

the otic bones in teleosts are: preotic,epiotic,opisthotic, pterotic and sphenotic. In higher vertebrates there are only the first three bones. In Aves, the otic bones are fused together inta a single bone known as periotic.

b-optic capsules:

The optic capsules do not fuse with the cranium to allow free movement of the eyes. In reptiles and birds, ossification occurs in the optic capsule forming a ring of sclerotic bones.

c-olfactory capsules:

ossification in the walls of the nasal capsules gives rise to the Ectothmoids. Among higher vertebrates, the side walls of the capsules give rise to turbinals or conchae.

3) Replacing bones in the jaws:

a-The upper jaw:

In tetrapodes, most of the palatoquadrate cartilage degenerates. Osification occurs into the ascending process forming the apipterygoid bone (Alisphenoid bone in mammals) and into the optic process to form the quadrate bone.

b- The lower jaw:

An Articular bone ossifies into the posterior end of meckel's cartilage while the rest of the cartilage disappears or remains as a cartilage Articulation takes place between the quadrate and Articular bones except in mammals where articulation of the lower jaw to the skull takes place by the dentary of the lower jaw and the squamosal of the skull, since the quadrate transformes into the incus and the articular becomes the malleus in the middle ear of mammals.

4) Replacing bones in the hyoid arch and gill arch:

In tetrapodes, the hyomandibular part of the hyoid arch ossifies to form the columella of the middle ear of amphibia. The rest of the hyoid arch together with the gill arches, form the hyobranchial skeleton which consist of the hyoid apparatus and the cartilage of the larynx.

Development of the dermatocranium:

The dermatocranium comprises a series of bones which developed directly from mesenchymal cells of the mesoderm in the head region The newely formed bones are called the membrane, the covering or the dermal bones and when they formed sink gradually from the overlying skin and become closely fixed to the already formed cartilage or replacing bones of the osteocranium. Therefore, the dermatocranium is a new addition of skeletal elements over the previosly well built osteocranium. After the Dermatocranium is completely formed, it consists of a strong units of closely fixed bones which can not be differentiation either they are cartilage bones or dermal bones.

The typical Dermatocranium is the best shown in a fossile reptilian group known as cotylosauria and represented by Seymouria , and from this type, The skull of recent chelonia develop.

In bony fishes, the covering or the dermal bones are first appear as large scales in the head region, the sinks gradually to the inside and become close to the osteocranium. These bones complete the roof and the side walls of the skull.

The dermal bones in the primitive tetrapod skull can be classified into six groups:

1-Median dorsal group:

They are front anterior backwards: nasals, frontals, parietal and postparientals.

2-Circus orbital group:

These bones are formed around the orbit: lacrinal, prefrontal, postfrontal and postorbital.

3-Temporal group:

Along the parietal laterally and just behind the orbits, these dermal bones are formed , Intertemporal, Supratemporal, tubular and squamosal which found outside the temporal group.

When this region possesses no foramen, the skull is called Anapsid skull as found in chelonia.

4-maxillary group:

The dermal bones of the upper jaw which cover the palatoquadrate from the maxillary arch. These bones are from front backwards: premaxillae, maxillae, jugales and quadratojugals.

5-palatal (the roof of mouth cavity)group:

These dermal or covering bones are: prevomers(vomers), pterygoids and a single median parasphenoid. Laterally there are palatines and ectopterygoids.

6-Mandibular group:

On the outer side of the lower jaw these bones are: the dentary,s plenial, postsplenial, angular and suprangular. On the inner side of the jaw, these dermal bones are formed, prearticular, coronoid, intercoronoid and precoronoid.

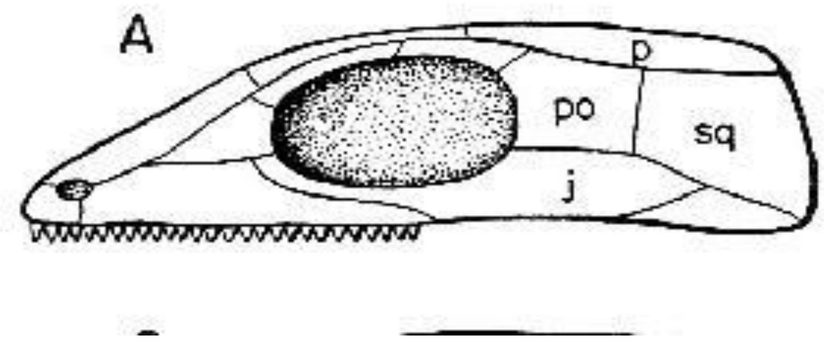
There are no dermal bones formed in the connection with either the hyoid arch or other the following gill arches.

Skull of modern Amphibia:

It is characterised by the great reduction in both cartilage and dermal bones. There are two exoccipital bones in the occipital region each exoccipital bone has an occipital condyl. the Basioccipital and Supraoccipital are not ossified.

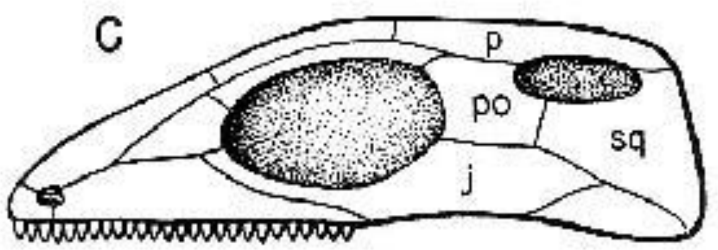
Skull of reptilia

The skull of primitive reptiles resembles that of primitive amphibians. The openings of the primitive reptilian skull are also the nostrils, the orbits and the parietal foramen or the foramen magnum. This type of skull is called **Anapsidian skull** and this type of skull is found in distinct reptiles such as in Cotylosaurian group and still present in the case of colonia. During the evolution of reptilian skull, fenestration occurred in the temporal region which found just behind the orbit.



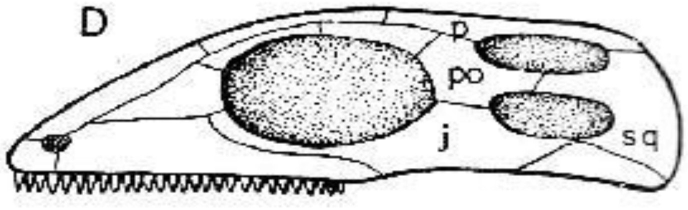
Parapsidian skull

which found in distinct reptilia such as inIchthyosaurian group contains an upper temporal fossa or the supra temporal fossa. This fossa are bounded laterally by the postorbital and squamosal. From this type of skull, the skulls of modern lizard were devolved.



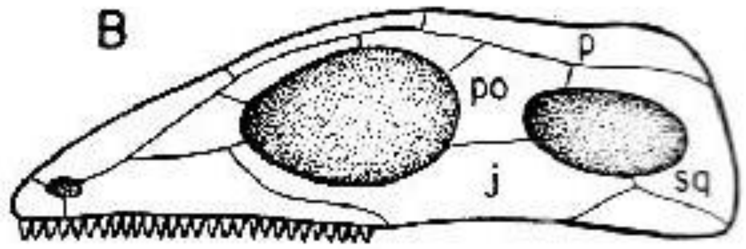
Diapsedian skull

which found in Rhynochocephalian group possesses two temporal fossae, the supra and the infera temporal fossae, between the upper and lower fossae, there are the postorbital and squamosal bones, forming the upper temporal arcade, while the arch lateral or ventral to the lower fossa is called the lower temporal arcade formed by the jugal and quadratojugal bones. From this type of skull, the skull of Aves is evolved



Synapsidian skull

Which found in distinct reptilia such as in Theromorphian group and in mammal- like reptiles (Therapsida), contains only the lower fossa or the infera temporal fossae which lies more ventral, this fossa is bounded laterally by jugal and quadratojugal bones, from this type of skull, the skull of mammals is evolved.

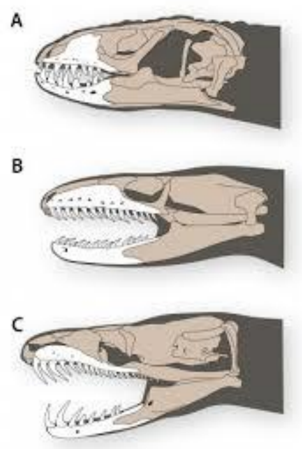


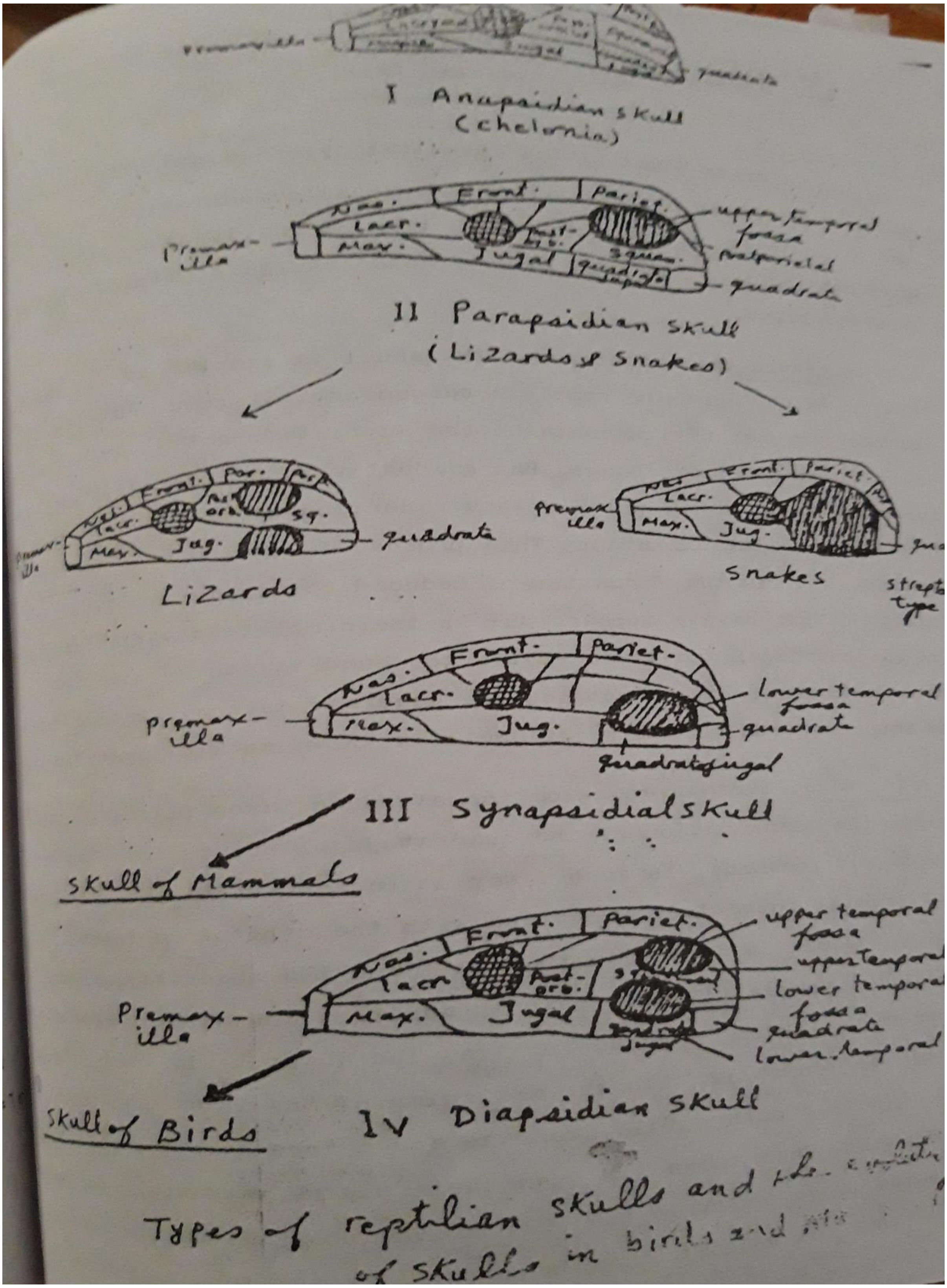
<u>Evolution of skulls of lizard and snake from the parapsidian type.</u>

The quadrate bones in the ancestral type are closely fixed from front and the squmosals from above and thus they are not movable in the skull, such type of skull is known as Monicostylic type and from this type, the skull of lizards and snakes were developed.

In lizards the structure of skull is similar to the ancestral type, in which there are complete cercum orbital group and jaw group and the temporal region contains the supra temporal fossa and postorbital and squanosal bones. But gradually reduction of the bones of upper jaw group takes place, this reduction occurs by a process of bony decay during evolution, this process is called emargination which results in the formation of reduced cavity in front of the quadrate. This cavity appears due to the complete disappearance of the quadratojugal and its enable the quadrate to move freely when the mouth open or mobile. The quadrate is now attached only by the squamosal and such type of the skull is known as Streptostylic type.

In snakes, further emargination of bones takes place. In this ophidian the emargination of the quadratojugnal occurs and also extended upwards and forwards, in such away it becomes continuous with the supratemporal fossa from above and with the orbital from front. A large vacuole is formed in the skull and the quadratojugal and the postorbital completely disappear in addition the supra temporal bones and squamosal become reduced in size. The quadrate is very large and articulates ventrally with the articular of the lower jaw. This leads also to a more mobile quadrate and a more streptostylic type of the skull. Thus snakes can open their mouths very widly to swallow large sized preys and also the wall of pharynx contain certain muscles that can relax and delicates the pharynx in addition to the large teeth on the maxillae which they are called the poisonous fangs.




I Anapsidian skull
(chelonia)
Nas.
Front.
Pariet.
Lacr.
Max.
Jugal
Premax-
illa
upper temporal
fossa
quadrate
II Parapsidian skull
(Lizards & Snakes)
Par.
Sq.
Jug.
quadrate
Lizards
Snakes
III Synapsidial skull
lower temporal
fossa
Quadratojugal
Skull of Mammals
Post-
orb.
IV Diapsidian skull
Skull of Birds
Types of reptilian skulls and
of skulls in

Evolution of skulls of Birds the Diapsidian type:

The Diapsid reptilian skull possesses two temporal fossa and from this type the early avian skull is drived. The postorbital disappears in most birds and thus the supratomporal fossa becomes continous with the infra temporal fossa ventrally and with the orbit anteriorly. The upper temporal arcade is lacking and the two fossae are fused. Therefore a large cavity or vacuole appears in this region of the skull of all birds known as the orbit.

The anterior part of the skull becomes elongated to form the back which it is considered as the expanded premaxlliae and dentaries of the upper and lower jaws.

The foessil Avian skull carries teeth, a character which indicates it reptilian ancestors.

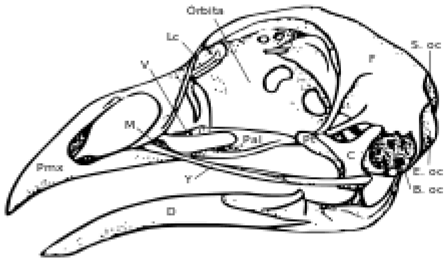
In Gallus domesticus, the bones of the skull are greatly fused together. Due to the elongation of the anterior part of the skull the nostrile is shefted anteriorly and thus a new cavity arises interbetween it and the orbit called the preorbital fossa.

The dorsomedian group of bones in Gallus possesses, the nasals which lie inbetween the nostrils in front and preorbital fossae behind and very large frontals which contain small processes supporting the posterior parts of the orbits known as the postorbital processes and behind the frontal lies the parietal.

In the circum orbital group, the bones are highly reduced and is represents only by the lacrymal. The skull of Gallus possesses vertical orbitosphenoid bone separating the eye from the brain.

The temporal group is also reduced being represented only by the squamosal and from it arises a process which meets the postorbital process forming the zygomatic process of squamosal.

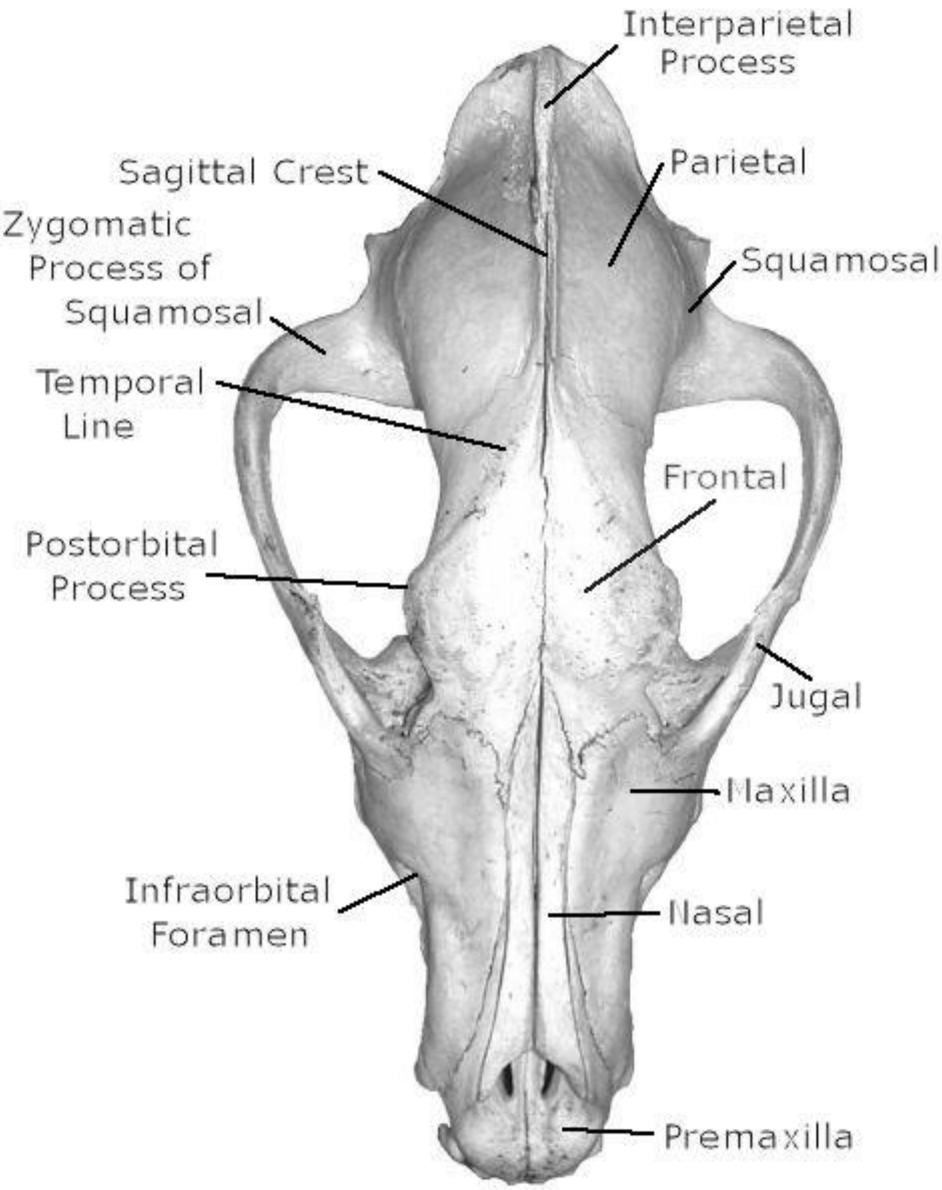
In the upper jaw, the two premaxillae are fused together to form a single and elongated beak. The maxilla, quadratojugal form as a slender rod of bone that bounds the orbit ventrally .



Evolution of skull of mammals from the synapsidian type

During evolution to form the skull some modification such as reduction, fusion and translocation take place:

1. the anterior part of the skull is prolonged forward to form the snout.
2. Post orbital and supra temporal disappear thus the orbit becomes confluent with the infra temporal fossa
3. In the dorsomedian group of bones:
   - a new bone called interparietal is developed.
4. The quadratojugal completely disappears and the quadrate become separated from the posterior region of the skull
5. The articulation between the jaws occurs by the squamosal of the skull and the dentary of lower jaw


Interparietal
Process
Sagittal Crest
Parietal
Zygomatic
Process of
Squamosal
Squamosal
Temporal
Line
Frontal
Postorbital
Process
Jugal
Maxilla
Infraorbital
Foramen
Nasal
Premaxilla

Circulatory System in Vertebrates

In order to carry on vital life processes, all animals, from the simplest protozoans to the most complex vertebrates, required that

1-Food absorbed through digestive tract and oxygen collected in respiratory organs, must be transported to all parts of the body

continually, for metabolism

2-Waste products of metabolism (Co_2, nitrogenous wastes, etc.) must be transported from the sites of their productions to excretory organs for their quick elimination from body.

3-Hormones from endocrine tissues, substances for maintaining homeostasis or constancy of internal environment, and providing immunity from diseases, must be conveyed to suitable sites for utilization.

For these and other reasons, an adequate internal system for circulating nutrients and other materials throughout the body becomes necessary, called circulatory system. In one-celled body of protozoans, distribution occurs through cyclosis or streaming movements of cytoplasm. In simple and less active multicellular animals (Porifera Coelenterata, Helminthes, etc.) exchanges occur by simple diffusion between various adjacent parts of their bodies. But most higher invertebrates and vertebrates are large and active, with most body organs and tissues well removed from exterior or gut. For them, diffusion alone cannot suffice. Thus, they possess a well-developed circulatory system for rapid internal transport of gases, nutrients, wastes, etc.

Parts of Circulatory System

Chordates have a completely closed circulatory system (Fig. 1), further distinguished into two systems, blood vascular and lymphatic, having parts as follows:-

1-Blood vascular system. It consists of heart, arteries, veins, capillaries and blood, (i) Blood consists of fluid plasma and free cells or blood corpuscles, (ii) Heart is a modified blood vessel with muscular walls. It contracts periodically to pump blood through body, (iii) Arteries are blood vessels that cairy blood away from the heart (iv) Capillaries are minute tubes with thin walls in tissues, that connect the smallest arteries (arterioles) with the smallest veins (venules). (v) Veins carry blood towards heart from capillary networks.

When blood flows through capillaries connected by arteries and veins, the blood vascular system is said to be 'closed', as in annelids and vertebrates. On the other hand, mollusc's and arthropods lack capillaries and have an lacunar' system. The blood pumped by their heart through ''open' or blood vessels to various organs, passes through body spaces or sinuses comprising the haemocoel.

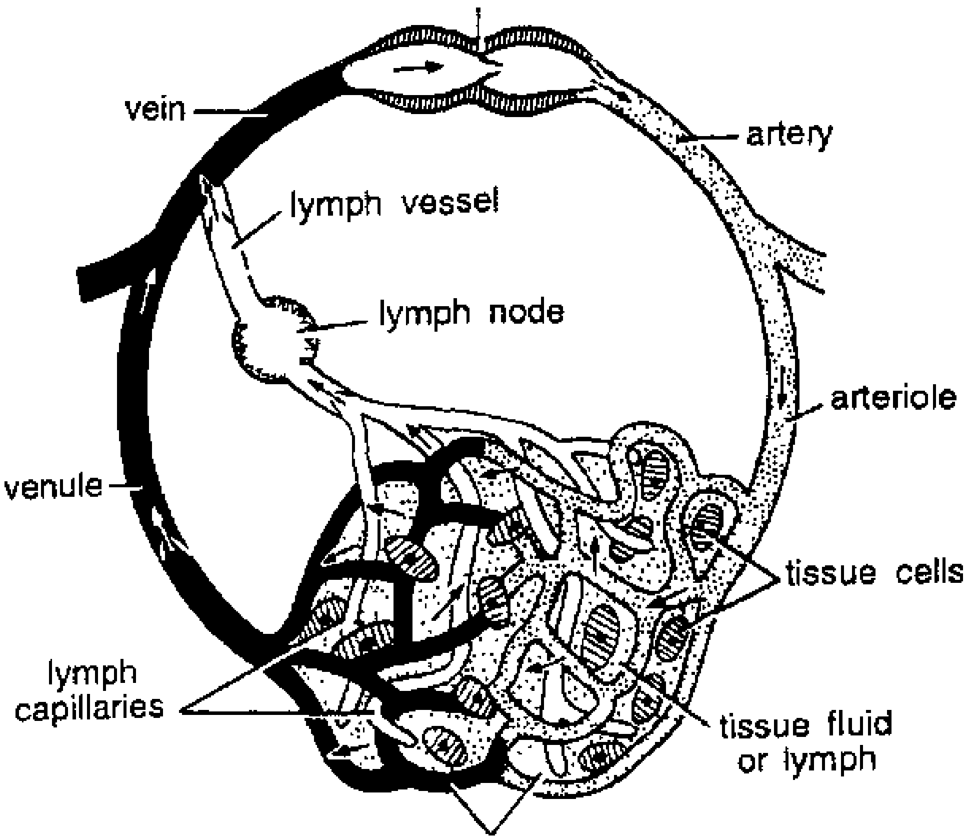
2 -Lymphatic system. It occurs exclusively in chordates, except cyclostomes and cartilaginous fishes, and consists of lymph and lymph channels

i) Lymph is the tissue fluid, lying between and bathing body cells. It is similar to blood plasma but lacks the red blood corpuscles and some proteins, (ii) Lymph capillaries forming a network of minute, blind-ending channels, collect lymph.

(iii) Lymph vessels are larger thin-walled vessels formed by the union of lymph capillaries, and finally emptying into veins, (iv) Lymph nodes found only in mammals on lymph vessels, produce lymphocytes of blood and form an important link in body's defense mechanism In cyclostomes and chondrichthyes no lymphatics are present but little sinusoids are found, representing the first stage of development Bony fishes and all tetrapodes are provides with lymphatic system. But as far as circulation is concerned, it is active in amphibian due to development of lymph heart. Lymphatic glands first appeared in reptiles and found in birds and mammals as well.

Blood vascular system has undergone some striking changes during the evolution of vertebrates. These are mostly correlated with shift from gills to lungs as the site for external respiration during transition from water to land and with the development of an efficient, high pressure circulatory system necessary for an active terrestrial life.

Fig. 1. Fundamental structure and parts of a typical mammalian circulatory system.



Evolution of Heart in Vertebrates

In the embryo, two longitudinal endothelial tubes formed by mesenchyme in ventral mesentery below archenteron, fuse together to give rise to the heart. The vertebrate heart is built in accordance with a basic architectural plan (Fig. 2). It is a sac-like muscular organ comprising a series of chambers, that receives blood from veins and pumps it through arteries.

I - Single-chambered heart

Cephalochordata. In a primitive chordate, such as Branchiostoma, a true heart is lacking. Instead a part of ventral, aorta below pharynx becomes muscular and contractile. Some zoologists consider it as a single-chambered heart.

Progressive modifications of heart from primitive to higher chordates occurs on the following lines:

1- Cardiac tube forms chambers due to constrictions

2-Each chamber tends to divide into two separate chambers due to formations of partitions.

3-Heart gradually shifts from just behind head (fishes, amphibians) near gills ' into thoracic cavity (amniotes) with elongation of neck and development of lungs.

I I -2-Chambered, single circuit venous hearts

Cyclostomes. Simplest conditions of vertebrate heart is seen in cyclostomes (ammocoete larva, lamprey, hagfish). It shows a linear series of 4 chambers: sinus venosus, atrium, ventricle and a small conus arteriosus, through which blood flows in that sequence. It is present in the common body cavity along with other visceral organs.

Elasmobranchs. Heart of a cartilaginous dogfish is typical and generalized for most fishes .It is a muscular and dorso-ventrally bent, S-shaped tube consisting of 4 chambers arranged in a linear sequence. Of these, sinus venosus and conus arteriosus are accessory chambers. Only auricle and ventricle are true chambers so that heart is considered two-chambered in fishes. Thin-walled sinus venosus receives venous blood of body

through larger veins (common cardinal and hepatic), serves chiefly as a reservoir and opens anteriorly into atrium through the sino-atrial aperture guarded by a pair of valves. Atrium is large, thin-walled, elastic and muscular chamber lying dorsal to ventricle. It opens ventrally into ventricle through an atrio-ventricular aperture guarded by a pair of valves. Ventricle has very thick and muscular walls. It opens into a muscular tube of narrow diameter, the conus arteriosus, having a series of semilunar valves. All the valves of heart prevent back flow or regurgitation of blood.

Heart of fishes is enclosed in a small pericardial cavity separated from general coelom by a transverse septum. In front of pericardial cavity, conus becomes continuous with the ventral aorta. In elasmobranchs, transverse septum is perforated by a pair of openings through which pericardial cavity communicates with coelom.

Teleosts. Heart of bony fishes resembles in all respects that of elasmobranchs. In some Chondrostei (Polypterus) and Holostei(Lepidosteus), conus is fairly long with numerous valves. In Amia, conus and number of its valves are reduced. While in Teleostei, conus is much reduced, or even absent, as it fuses with ventricle and retains a single pair of semilunar valves Instead, the part of ventral aorta in contact with conus becomes greatly enlarged with thick muscular walls, and called bulbus arteriosus. It is elastic and in flates like a balloon when the ventricle contracts.

In fishes, heart is small, 2-chambered and with a single circuit of blood circulation. All blood passing only once through heart is non-oxygenated It is pumped into gills for aeration before distribution to body. Such a heart is termed a branchial or venous heart.

(Ill) 3-Chambered transitional hearts

Dipnoi. Correlated with the shift from aquatic (gills) to terrestrial respiration (lungs), heart and aortic arches also become modified. Parallel with the systemic circulation, a new shorter pulmonary circulation develops so that aerated blood from lungs (or swim bladder), returns directly to the heart without making a detour of the whole body .Atrium of lung fishes (and most urodele amphibians) is divided by an incomplete inter-auricular septum, perforated by the foramen ovale, into right and left chambers or auricles .This results in a mixing of oxygenated blood received from lungs into left auricle, and deoxygenated blood from rest of body into right auricle. A partial partition also divides the ventricle, while a horizontal septum divides the conus of lung fishes into a dorsal and a ventral part.

Amphibians. Amphibians heart (anurans) shows an advance over the piscine heart. Atwisting or curving results in dorsal atrium shifting anteriorly to ventricle. Similarly, sinus venosus opens into the right atrium dorsally instead of posteriorly. The inter-auricular septum is complete without foramen ovale. This keeps the oxygenated and deoxygenated bloods separate. Ventricle is undivided or single, but its thick muscular wall raised into trabeculae permitting only little mixing of the two bloods. In urodeles, conus is reduced and replaced by a bulbus, arteriosus. In anurans from left ventricle, on its anterolateral margins conus (or truncus) arteriosus arises which is prominent and divided by a spiral valve which directs deoxygenated blood into pulmonary vessels and oxygenated blood into systemic vessels. The lumen of conus arteriosus is called, pylangium is occupied by spiral valve (= septum bulbf). This valve is very complicated in its disposition. It is attached to the walls of conus dorsally and free at other three faces. It divides the lumen of conus arteriosus into two chamber cavum pulmocutaneum and cavum aorticum.

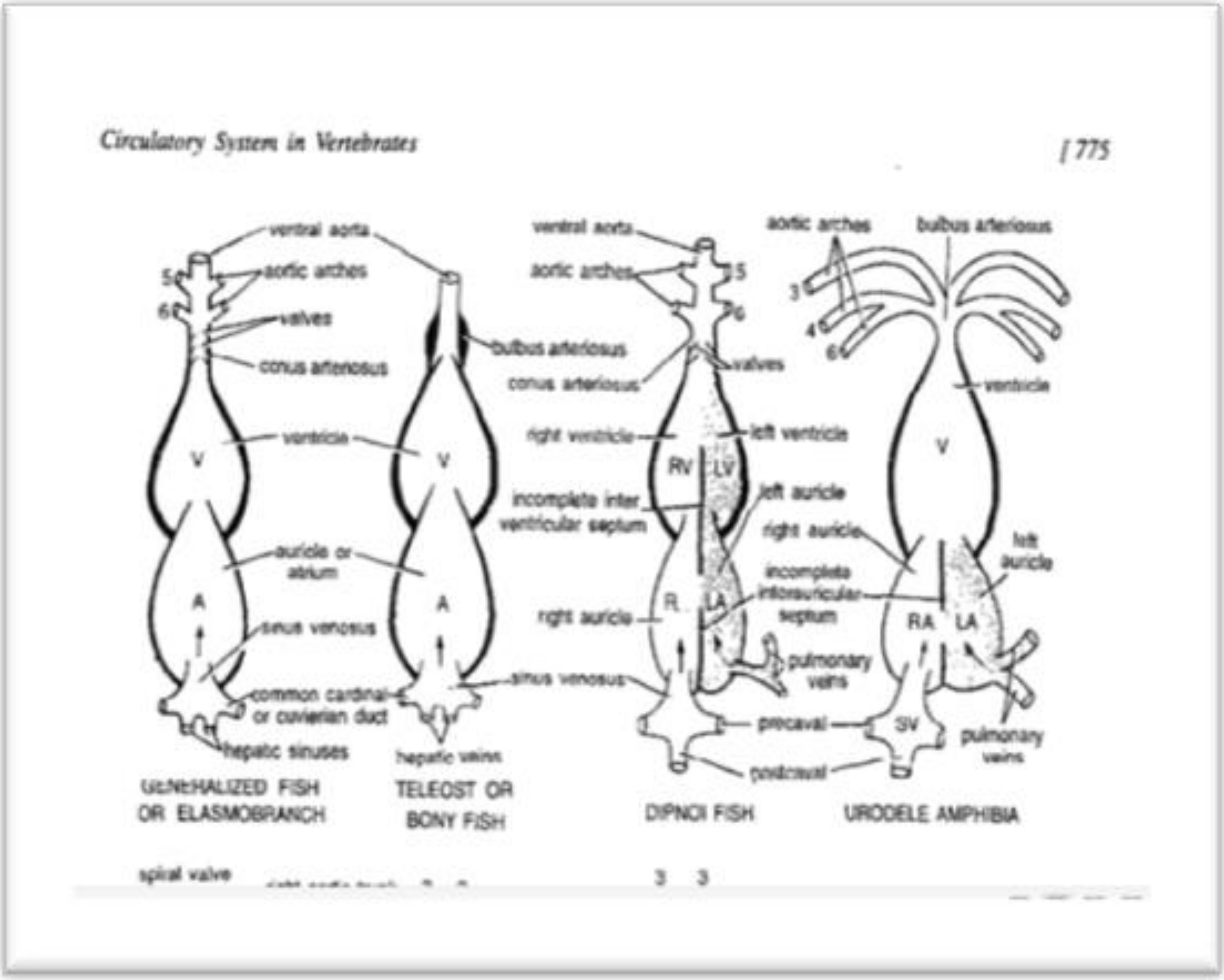
Reptiles. Heart of reptiles shows further improvement over that of amphibians. It becomes more strongly muscular. It shows two auricles and two ventricles. In most reptiles, ventricle is partially divided by an incomplete inter-ventricular septum, which reduces the mixing of oxygenated and deoxygenated blood. In crocodilians, this septum is complete thus making an effective 4-chambered heart, having two auricles and two ventricles. However, complete separation of oxygenated and deoxygenated blood is not achieved. The right and left systemic, aortae carrying arterial and venous bloods, respectively join to form the dorsal aorta in which the two bloods get mixed before distribution. Besides, a small opening, called foramen of panizza connecting the two aortae at their base, brings about some mixing of blood. In crocodiles foramen panizza becomes obliterated. A sinus venosus is present in all reptiles, large in turtles small in snakes and lizards, and distinct internally in crocodiles. Conus and ventral aorta of embryo become split in the adult into three distinct trunks-pulmonary and right and left systemic.

Amphibian heart with only 3 major chambers (2 auricles, 1 ventricle), and reptilian heart with partially 4 chambers (2 auricles, 2 incomplete ventricles), permit a partial mixing of arterial and venous bloods before distribution. Thus, they represent transitional hearts showing a midway condition between 2-chambered heart of fishes with a single circulation and 4-chambered hearts of birds and mammals with double circulation and complete separation of arterial and venous bloods.

(IV) 4-Chambered, double circuit

pulmonary hearts

Birds and mammals. Birds and mammals have a completely divided ventricle, so that their heart is completely 4-chambered (2-auricles, 2 ventricles), Left auricle receives aerated blood from lungs pours into left ventricle which pumps it to entire body through systemic circulation. Right auricle receives deoxygenated blood returning from body passes it to right ventricle which pumps it to lungs for reoxygenation. Thus there is double circulation in which there is no mixing of oxygenated and non-oxygenated blood at all. Such a heart is known as a pulmonary heart. Sinus venosus is absent being completely incorporated into right auricle which directly receives two precavals postcaval. The union of sinus with right auricle in some cases is marked externally by a groove called sulcus terminalis and internally by a muscular ridge, crista terminalis which separates right auricular chamber (sinus venerum) from smaller ventral chamber (appendix auricular) .Similarly, the left auricle receives blood directly through pulmonary veins. Primitive conus arteriosus is completely replaced by a pulmonary aorta leaving the right ventricle for lungs, and a single systemic aorta leaving the left ventricle for body. All major vessels have valves basally at the point of exit from or entry into heart. Blood from the walls of the heart is brought to the auricle by means of coronary sinus in right atrium. The opening of the sinus is guarded by valves called coronary valve (= Thebsian valve). The inner surface of right auricle wall is marked by small depressions of Thebesian foramina in which fine veins directly pass the blood from atrial walls to right atrium. Although, interauricular septum is complete in adults but a fine depression, fossa ovalis is present which marks the site of foramen ovale. The fossa ovalis is surrounded by a prominent ridge annulus ovalis.


Circulatory System in Vertebrates
[775
ventral aorta
aortic arches
valves
conus arteriosus
bulbus arteriosus
ventricle
auricle or atrium
sinus venosus
common cardinal or cuvierian duct
hepatic sinuses
hepatic veins
V
A
5
6
3
4
right ventricle
left ventricle
RV
LV
incomplete inter ventricular septum
left auricle
right auricle
incomplete interauricular septum
RA
LA
pulmonary veins
precaval
postcaval
SV
aortic arches
bulbus arteriosus
left auricle
GENERALIZED FISH OR ELASMOBRANCH
TELEOST OR BONY FISH
DIPNOI FISH
URODELE AMPHIBIA
spiral valve

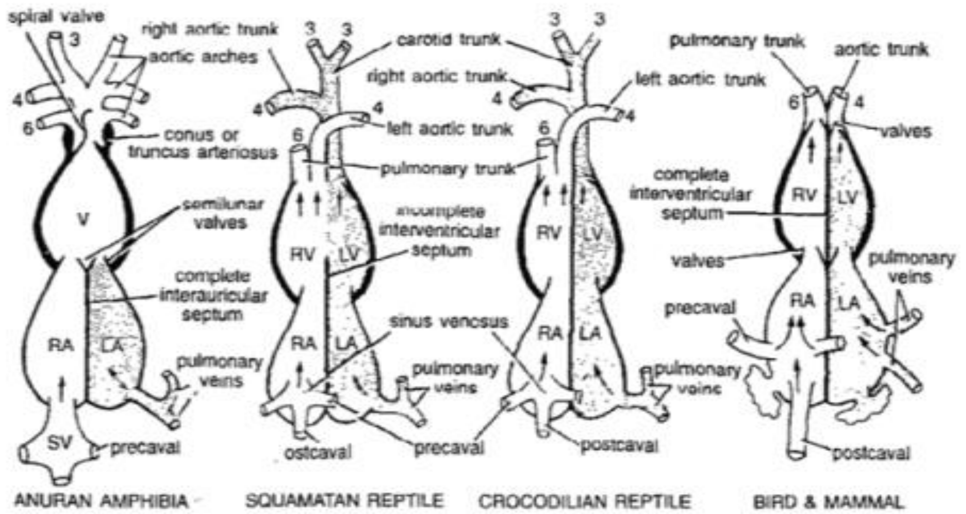


Fig. 2. Successive modifications of heart during evolution in different classes of vertebrates. 1—6 represent aortic arches. Shaded chambers contain mainly oxygenated blood. LA—left auricle, LV—left ventricle. RA—right auricle. RV—right ventricle. SV—sinus venosus

Modifications of

Aortic Arches in Vertebrates

Basic embryonic plan. In a typical vertebrates embryo, the major arterial channels include a ventral aorta, a dorsal aorta and usually 6 pairs of aortic arches connecting ventral aorta with the dorsal aorta (Fig. 3). Blood leaves the heartomplexity of heart on account of a shift from gill respiration to lung respiration. The modifications mainly concern the aortic arches which undergo a progressive reduction in number from lower to higher vertebrates

Primitive vertebrates. In Branchiostoma (amphioxus), nearly 60 nearly 60 pairs of aortic arches are present, connecting the ventral and dorsal aortae .In Petromyzon, 7 pairs of aortic arches are found .In other cyclostomes the number varies from 6 (Myxine) to 15 pairs (Eptatretus).

Fishes. The primitive elasmobranch

Heptanchus) has 7 pairs of aortic arches. Most of the fish embryos present primitive plan with 6 or more pairs of aortic arches, each passing through a gill. But, in adult condition, the number is reduced to 4 or 5. In most sharks (elasmobranchs), only 5 pairs (II, III, IV, V, and VI) are functional. The first gill it forms the spiracle which is non-functional as a gill. Accordingly the first arch (mandibular) is absent or represented by an efferent pseudobranchial artery. In most teleosts or ony fishes, I and II arches tend to disappear, so that only 4 pairs (III, IV, V and VI) remain functional. In Polypterus and lungfishes (Dipnoi) gills are poorly developed, so that a pulmonary artery arises from the efferent part of the VI arch on each side and supplies blood to the developing air bladder or lung. In Protopterus, the III and IV embryonic arches are uninterrupted by gill capillaries.

In elasmobranchs and lungfishes, each arch forms one afferent and two efferent arteries (by splitting) in each gill. In teleosts or bony fishes each gill has one afferent and one efferent artery in tetrapods, true internal gills are absent so that aortic arches do not break up into afferent and efferent arteries. I and II arches totally disappear in all tetrapods.

Amphibians. With the introduction of lungs as main respiratory organs and the diminishing importance of gills, the aortic arches of amphibians show a modification from those of fishes.

Urodeles or the tailed amphibians live in water and retain external gills permanently in addition to lungs. Accordingly, their aortic system shows only partial shift from condition in fishes. 4 pairs of arches (III to VI) are usually present although in some forms (Necturus, Siren, Amphiuma), V arch is incomplete, reduced or absent. Thus tailed amphibians show transition from 4 to 3 pairs of aortic arches. Ill arch forms the carotid arches, IV the systemic arches. The radix or lateral aorta between III & IV arches may persist as a vascular connection termed ductus caroticus. VI arch on either side becomes the pulmocutaneous artery or arch, supplying blood to skin and lungs. However, it also retains connection with radix aorta called ductus Botaili or ductus arteriosus.

In the larval stage of an anuran or tailles

amphibian, such as frog tadpole, arrangement of aortic arches is similar to an adult urodele, due to gill respiration. At metamorphosis, with loss of gills, aortic arches I, II and V disappear altogether Ductus caroticus also disappears so that the III or carotid arch takes oxygenated blood only to head region. IV or systemic arch on each side continues to dorsal aorta to distribute blood elsewhere except head and lungs. Ductus arteriosus also disappears so that VI or pulmocutaneous arch supplies venous blood exclusively to lungs and skin for purification. Thus, adult anurans exhibit only 3 functional arches, (III, IV and VI) which are also retained by the amniotes or higher vertebrates.

Reptiles. Reptiles are fully terrestrial

vertebrates in which gills disappear altogether and replaced by lungs. Only 3 functional arches (III, IV and VI) are present. But elongation of neck, posterior shifting of heart and partial division of ventricle brings about certain innovations in the aortic system.

1-Entire ventral aorta and conus split forming only 3 trunks-two aortic or systemic and one pulmonary

2- Right systemic arch (IV) arises from left ventricle carrying oxygenated blood to the carotid arch (HI) to be sent into head

3-Left systemic arch (IV) leads from right ventricle carrying deoxygenated or mixed blood to the body through dorsal aorta

4-Pulmonary trunk (VI) also emerges from right ventricle carrying deoxygenated blood to the lungs for purification

5-Ductus caroticus and ductus arteriosus are absent. But, ductus caroticus is present in certain snakes and lizards (Uromasitx), ductus arteriosus in some turtles, and both in Sphenodon. Reptiles also remain cold-blooded, like amphibians and fishes, due to mixing of blood.

Birds and mammals. Birds and mammals are warm-blooded because in both the ventricle is completely divided so that there is no mixing of oxygenated and unoxygenated bloods. As usual, 6 arches develop in the embryo, but only 3 arches III, IV, VI) persist in the adult. Other features are as follows

1-Ventral aorta is replaced by two independent aortae or trunks-(systemic and pulmonary.

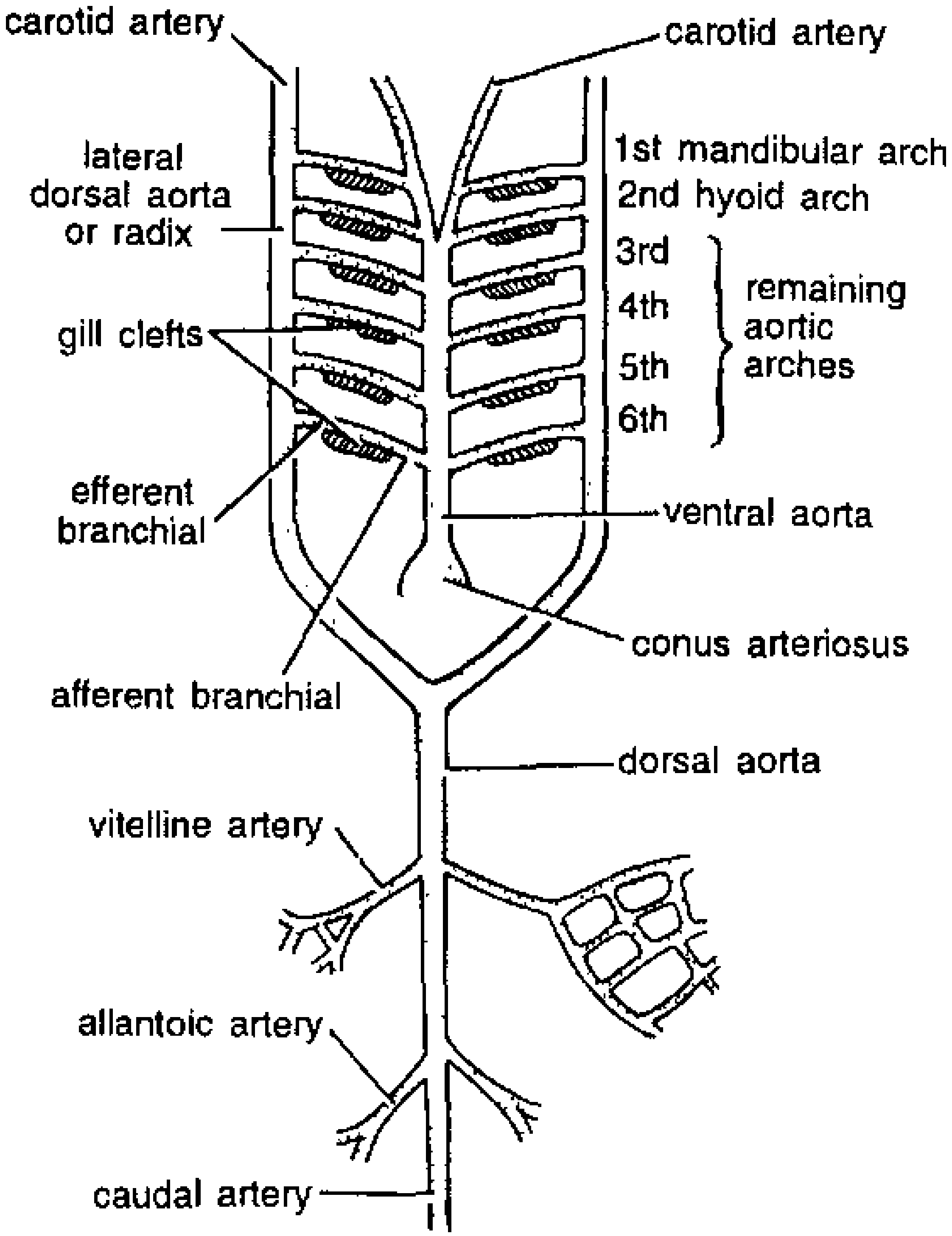
2-Arch IV is represented by a single systemic aorta, right in birds and left in mammals emerging from left ventricle and carrying oxygenated blood. Uniting with the radix aorta of its side it forms the dorsal aorta.

3-The only remaining part of the other lost systemic arch is represented by a subclavian artery, on left side in birds and on right side in mammals

4-Arch III with remnants of lateral and ventral aortae represents carotid .arteries, which arise from systemic aorta

5-Arch VI forms a single pulmonary trunk taking deoxygenated blood .from right ventricle to the lungs

6-Embryonic ductus caroticus and ductus arteriosus also disappear. The latter closes but persists until hatching or birth in some cases as a thin ligament of Botalli or ligamentum arteriosum.


carotid artery
carotid artery
lateral
dorsal aorta
or radix
1st mandibular arch
2nd hyoid arch
3rd
4th
5th
6th
remaining
aortic
arches
gill clefts
efferent
branchial
ventral aorta
conus arteriosus
afferent branchial
dorsal aorta
vitelline artery
allantoic artery
caudal artery

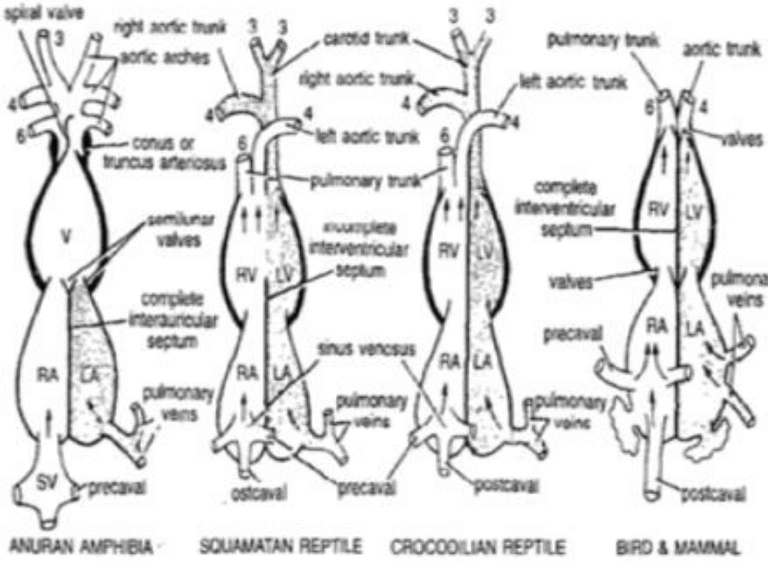
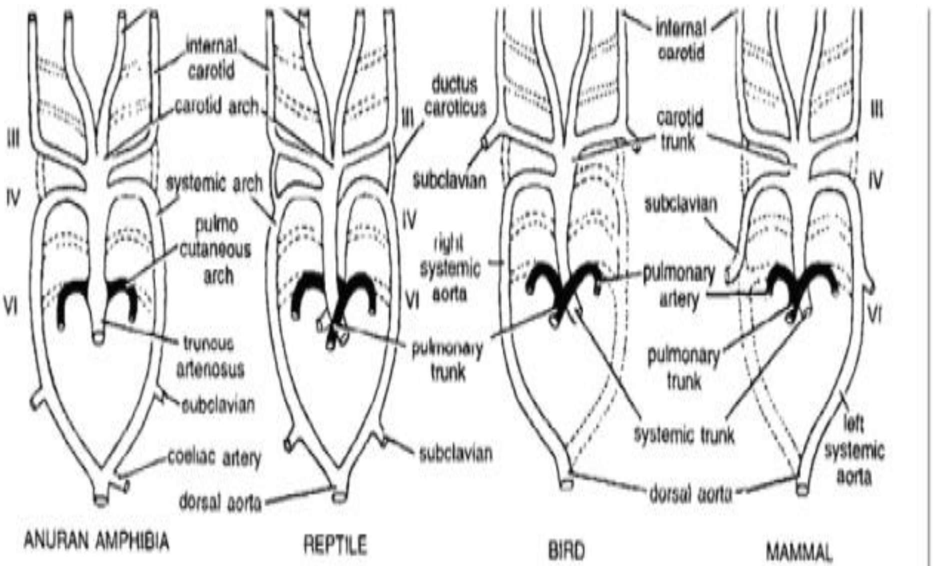


Fig. 2. Successive modifications of heart during evolution in different classes of vertebrates. 1—6 represent aortic arches. Shaded chambers contain mainly oxygenated blood. LA—left auricle, LV—left ventricle. RA—right auricle. RV—right



Venous System

Deoxygenated or venous blood from different parts of the body is returned to the heart via veins. Like arteries, the veins of all vertebrates also follow a basic pattern or fundamental plan.

(I) Embryonic veins

The venous system in early embryonic life of all vertebrates is relatively simple, similar and in accordance with the basic pattern. Most of the veins are paired and symmetrically arranged. The major basic embryonic veins include: (i) Cardinals (anterior, posterior, and common cardinal or ductus)

Cuvieri), (ii) lateral abdominal, (iii) vitelline (iv) subintestinal, and (v) caudal.

II] Modifications of veins in vertebrates

Modifications in adult vertebrates occur by either deletions or additions of some veins to the basic embryonic pattern (Fig. 5). Modifications are few in elasmobranchs but more numerous in tetrapods. In vertebrates, veins can be arranged in three

distinct categories- systemic or somatic, renal portal and hepatic portal. A fourth category of pulmonary veins and postcaval veins in added in lungfishes and tetrapods.

1-Systemic veins. Systemic or somatic veins collect blood from all parts of the body and empty into sinus venosus of the heart

a) Elasmobranchs. In adult cartilaginous fishes (dogfish), venous system is almost a blueprint of the basic architectural plan of the embryo. A few larger veins expand to form thin-walled sinuses. Blood from head and posterior region of body is collected by large, paired anterior and posterior cardinal veins respectively .On either side they open into the common cardinalor ductus Cuvieri, that passes inwards through transverse septum to enter the sinus venosus of heart. In fishes and salamanders, an inferior jugular vein also collects blood on either side from ventral part of head to join the common cardinal. In embryo, posteriorly, the two posterior cardinal veins remain continuous with a caudal vein collecting blood from tail. Each posteriorcardinal, or postcardinal, runs anteriorly along the outer margin of kidney, draining it through a series of renal veins, before joining the common cardinal. In adult dogfish, the old postcardinals become interrupted near anterior ends of kidneys .Instead new postcardinals (earlier subcardinal channels) develop along the inner margins of kidneys which they drain.

Blood from lateral wall and pelvic fin on either side is returned through a ventral or lateral abdominal vein. It receives a branchial vein from pectoral fin forming a short subclavian vein enters the common cardinal of its side. Abdominal veins are absent in bony fishes or teleosts. In some lungfishes (Neoceratodus), two abdominals fuse to form a single ventral abdominal vein which terminates into sinus venosus. Blood from liver is taken to sinus venosus through a pair of hepatic veins or sinuses.

Tetrapods. Embryonic tetrapods also

exhibit anterior, posterior and cardinal veins. In adult tetrapods, anterior cardinals persist as the internal jugular veins. The inferior jugular veins are absent. Common cardinals become the anterior venae cavae or precavals which join sinus venosus amphibians, reptiles) or directly enter the right auricle of heart (birds, mammals) when a sinus venosus is lacking. In some mammals, (man, cat) left precaval disappears, so that blood of left side enters right precaval through a branchiocephalic vessel.

In amphibians, two embryonic ventral or

anterior abdominal veins become fused in the adult to form a single median ventral abdominal vein But it terminates anteriorly into liver and no longer drains the forelimbs. In reptiles, abdominal veins remain paired throughout life and also

terminate into liver. They remain connected anteriorly with the hepatic portal system, and posteriorly with the renal portal system by (external iliac). In birds, they are modified into

epigastric and coccygeo-mesenteric veins. In mammals, abdominal veins are absent except in spiny anteater (Tachyglossus)

In air-breathing vertebrates, pulmonary veins drain the lungs and enter the left auricle. In lungfishes and amphibians, right and left vessels unite to form a common pulmonary vein opening into right auricle

2-Renal portal system. Blood collected from capillaries in different parts of body is returned directly to the heart through systemic veins and their tributaries. However, in some cases, the returning blood is forced to run through a secondary capillary network in kidneys or liver before being sent to the heart. This is called portal circulation. The vein carrying blood from one set of capillaries to another is termed a portal vein All the constituents in a portal circulation together form a portal system, named after the organ of body having the secondary capillary' network. Two portal systems exist in vertebrates: (i) renal portal and (ii) hepatic portal.

Renal portal system is not universally present in all vertebrates. Cyclostomes have no renal portal system. In vertebrates embryos, caudal vein trifurcates anteriorly into a subintestinal and two postcardinal veins, (basic pattern). In fishes, connection of caudal vein with subintestinal is lost, while the anterior parts of postcardinals are suppressed. As a result, the persistent posterior parts of postcardinals become renal portal veins which pour all blood from tail into kidneys through afferent renal veins. Inside kidneys, they contribute blood to the capillary network.

surrounding the mesonephric tubules, but never to the glomeruli. Thus .renal portal system drains only the tail in fishes

In amphibians and reptiles, an external iliac vein connects the renal portal and abdominal veins, so that the renal portal system drains the tail as well as the hind limbs. In tailless amphibians or anurans (frog), it drains only hind limbs, while in snakes, having no limbs, it drains only the tail. In Necturus, renal portal vein is directly continuous with postcardinal, as in the basic pattern.

In crocodilians and birds, renal portal system is degenerate and bypasses the kidneys. Only a very little venous blood enters the capillaries in kidneys while most blood from tail and hind limbs passes nonstop through kidneys and leads directly into the postcaval. In mammals, renal portal system is completely absent, except in monotremes, since blood from tail and hind limbs is drained solely by the postcaval.

3-Hepatic portal system. Hepatic portal system is of universal occurrence and essentially similar in all vertebrates. In the embryo, the firstvenous channels to form are a pair of vitelline veins (basic pattern) arising from the yolk sac or midgut to enter the sinus venosus of heart. Caudal vein from tail is continued forward beneath the digestive tract as a subintestinal vein, which usually joins the left vitelline vein. As liver develops, vitelline veins unite together forming a single hepatic portal vein in lesser omentum. The subintestinal vein also loses connection with caudal vein to become a part of hepatic portal system. It drains different parts of digestive tract)yolk sac, stomach, intestine, etc.), its various derivatives (pancreas, gall bladder, rectal gland etc.) and spleen, and passes it on to the sinusoids in liver. In adult sharks, vitelline veins remain paired and form hepatic sinuses

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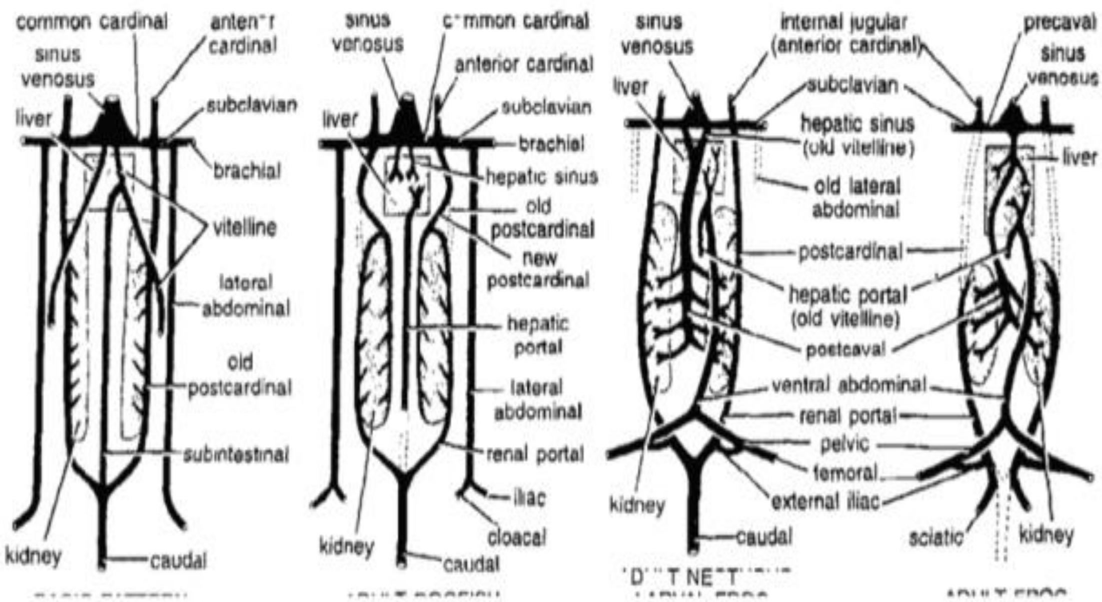


common cardinal
cardinal
sinus venosus
subclavian
liver
brachial
vitelline
lateral abdominal
old postcardinal
subintestinal
kidney
caudal
sinus venosus
anterior cardinal
subclavian
liver
brachial
hepatic sinus
old postcardinal
new postcardinal
hepatic portal
lateral abdominal
renal portal
iliac
cloacal
kidney
caudal
sinus venosus
internal jugular (anterior cardinal)
liver
subclavian
hepatic sinus (old vitelline)
old lateral abdominal
postcardinal
hepatic portal (old vitelline)
postcaval
ventral abdominal
renal portal
pelvic
femoral
external iliac
kidney
caudal
precaval
sinus venosus
liver
sciatic
kidney

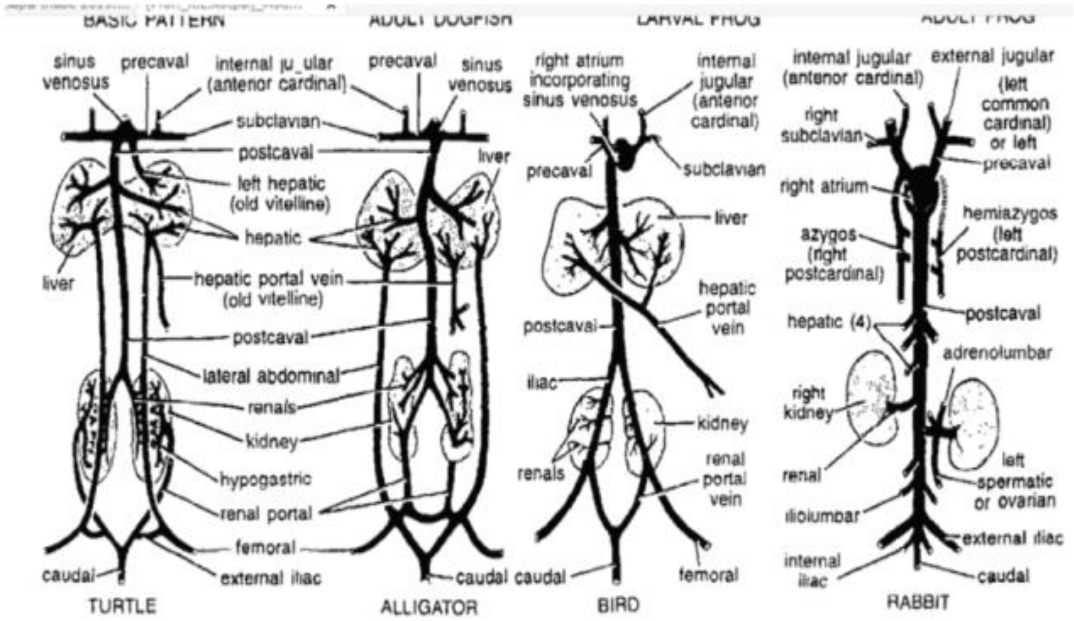


Fig. 5. Modifications of venous system in representative vertebrates. Broken line respresent embryonic vessels that have disappeared

Urinogenital System in Vertebrates

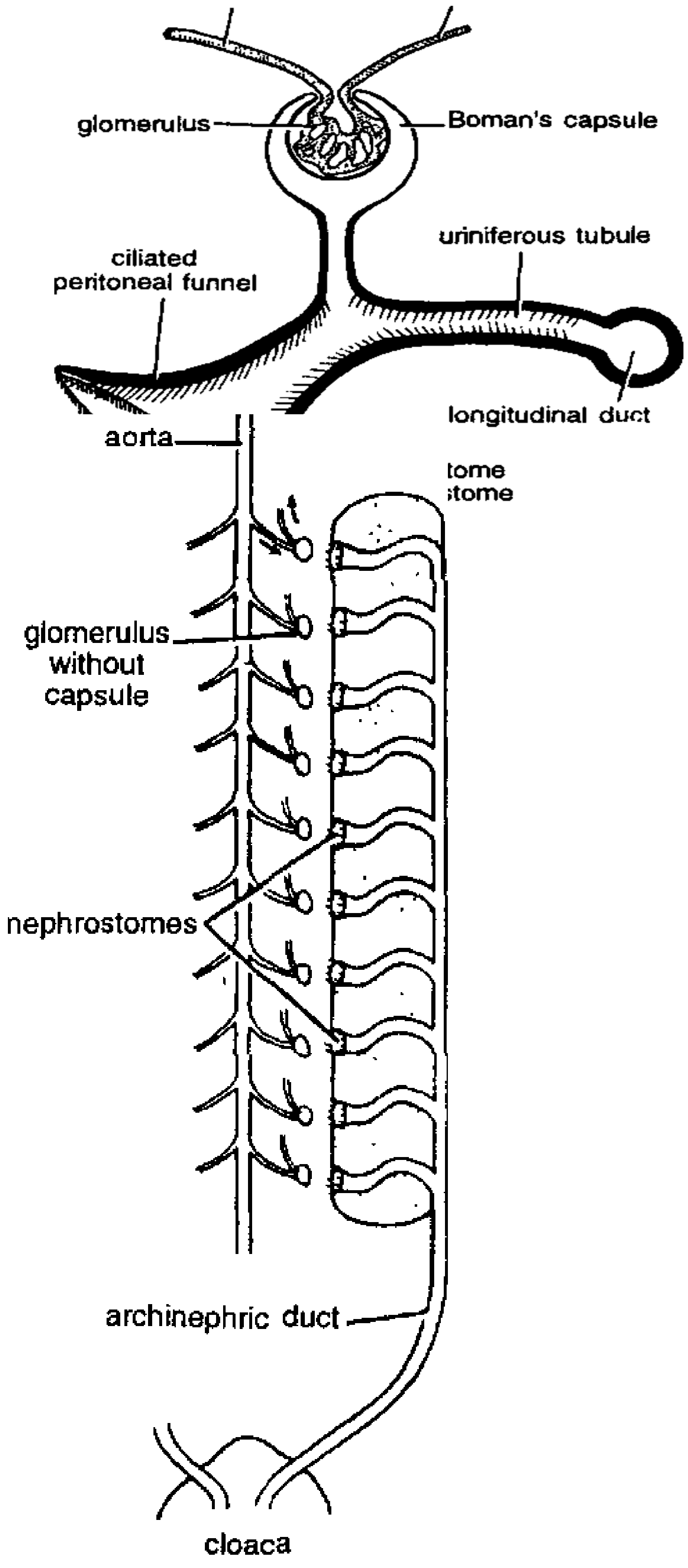
Urinary system of vertebrates includes kidneys and their ducts, while reproductive system includes male and female gonads and their ducts. Kidneys excrete harmful metabolic nitrogenous wastes and regulate the composition of body fluids, while reproductive organs perpetuate the species. Thus kidneys and gonads remain functionally unrelated .However, the two systems are intimately related morphologically in vertebrates because the male urinary ducts are also used for discharging gametes. For this reason, it is more convenient to treat and describe the two systems together as the urogenital or urinogenital system**.**

Vertebrate Kidneys and Ducts

1-Basic structure and origin. Vertebrate kidneys are a pair of compact organs, lying dorsal to coelom in trunk region, one on either side of dorsal aorta. They are all built in accordance with a basic pattern. Each kidney is composed of a (Z=3) large number of units called uriniferous tubules or nephrons. Their number, complexity and arrangement differ in different groups of vertebrates .Kidney tubules arise in the embryo in a linear series from a special part of mesoderm called mesomere or nephrotome (Figs. 1, 5 & 6). It is the ribbon-like intermediate mesoderm, running between segmental mesoderm (epimere) and lateral plate mesoderm (hypomere) on either side along the entire trunk from heart to cloaca. A uriniferous tubule is differentiated into three parts: peritoneal funnel, tubule and Malpighian body.

a) Peritoneal funnel near the free end of a uriniferous tubule is a funnel-like ciliated structure called peritoneal funnel. It opens into coelom (splanchnocoel) by a wide aperture, the)

coelomostome or nephrostome, for draining wastes from coelomic fluid. Nephrostomes are usually confined to embryos and larvae and considered vestiges of a hypothetical primitive kidney.


glomerulus
Boman's capsule
uriniferous tubule
ciliated
peritoneal funnel
longitudinal duct
aorta
tome
stome
glomerulus
without
capsule
nephrostomes
archinephric duct
cloaca

.Fig. 1. Structure of an embryonic kidney tubule

Fig. 2. Hypothetical primitive ancestral

vertebrate kidney or archinephros.

(b) **Malpighian body**. A tubule begins as a blind, cup-like, hollow, double-walled Bowman's capsule. It encloses a tuft of blood capillaries called glomerulus. It is supplied blood by a branch of renal artery, called afferent glomercular arteriole. An efferent glomerular arteriole emerges out of glomerulus to join the capillary network surrounding the tubule.

Bowman's capsule and enclosed glomerulus together form a renal corpuscle or Malpighian body. Encapsulated glomeruli are termed internal glomeruli which are common. Those without a capsule and suspended freely in coelomic cavity are called external glomeruli (embryos and larvae).Capsules without glomeruli are termed aglomerular, such as found in embryos, larvae and some fishes.

(c) **Tubule.** Malpighian bodies filter water salts and other substances from blood. During passage through tubules more substances are secreted .into filtrate, while some are reabsorbed

All the tubules of embryonic kidney are convoluted ductules that conduct the final filtrate to a longitudinal duct which opens behind into mbryonic cloaca

2-Archinephros. Archinephros is the name given to the hypothetical primitive kidney of ancestral vertebrates (Fig. 2). It may be regardedas a complete kidney or holonephros as it extended the entire length of coelom. Its tubules were segmentally arranged, one nephron for each body segment. Each tubule opened by a peritoneal funnel or nephrostome into coelom. Near each nephrostome was suspended in coelom an external glomerulus (without capsule). All the tubules were drained by a common longitudinal Wolffian or archinephric duct opening behind into cloaca.

Such a hypothetical archinephros is found today in the larVae of certain Myxine), but not in any adult vertebrate. It)cyclostomes

supposed to have given rise to all the kidneys of later vertebrates during the course of evolution .Modern vertebrates exhibit three different kinds of adult kidneys : pronephros, mesonephros and metanephros. It is supposed that these represent the sequence or three successive stages of (z-3) development of the ancestral archinephros, and all the three are never functional at the same time.

3- Pronephros. In the embryos of all vertebrates, the first kidney tubules appear dorsal to the anterior end of coelom, on either side .These are called pronephros as they are first to appear (Fig. 3). Pronephros is also termed head kidney due to its anterior position immediately behind the head. A pronephros consists of 3 to 15 tubules segmentally arranged, one opposite each of the anterior mesodermal somites. There are only 3 pronephric tubules in frog embryo, 7 in human embryo and about a dozen in chick embryo. Each tubule opens into coelom by a funnel or nephrostome. Also projecting into coelom near each tubule and not connected with it is an external or naked glomerulus without capsule. In some cases, glomeruli unite to form a single compound glomerulus, called glomus. Glomus and tubules become surrounded by a large pronephric (z-3) chamber derived from pericardial or paraperitoneal cavity. Originally each tubule has its individual external aperture, but secondarily, all tubules of a pronephros open into a common pronephric duct, leading posteriorly into the embryonic cloaca.

Pronephros is functional, if at all, only in embryonic or larval stage. It is mostly transitory and soon replaced by the next stage or mesonepliros. However, a pronephros is retained throughout life in adult cyclostomes and a few teleost fishes, but it is nonurinary and mostly lymphoidal in function.

4-Mesonephros. In the embryo, a mesonephros develops from the middle part of intermediate mesoderm, posterior to each pronephros soon after its degeneration (Fig. 4). At first, the new mesonephric tubules join the existing pronephric duct and are segmentally disposed Later on the tubules multiply by budding so that their segmental arrangement is disturbed due to increased number of tubules per segment. Tubules of pronephros and mesonephros develop similarly and are homologous. However, mesonephros is functionally better than pronephros because mesonephric tubules are more numerous, longer and develop internal glomeruli enclosed in capsules forming Malpighian bodies. Thus, they remove liquid wastes directly from glomerular blood rather than indirectly from coelomic fluid as in case of a pronephros. The mesonephros is also termed Wolffian body. With disappearance of pronephros, the old pronephric duct becomes the Wolffian or mesonephric duct. In amniotes (reptiles, birds and mammals mesonephros is functional only in the embryos replaced by metanephros in the adults. In fishes and amphibians, mesonephros is functional both in embryos as well as adults. In sharks and caecilians, tubules extend posteriorly throughout the length of coelom. Such a kidney is sometimes called a posterior kidney or opisthonephros whereas in adult anurans, urodeles and embryonic amniotes, the mesonephros does not extend posteriorly. Mesonephric kidney is not metamerie, but in myxinoids it is segmental and sometimes called a holonephros. Nephrostomes are generally lacking in mesonephros of embryonic amniotes.

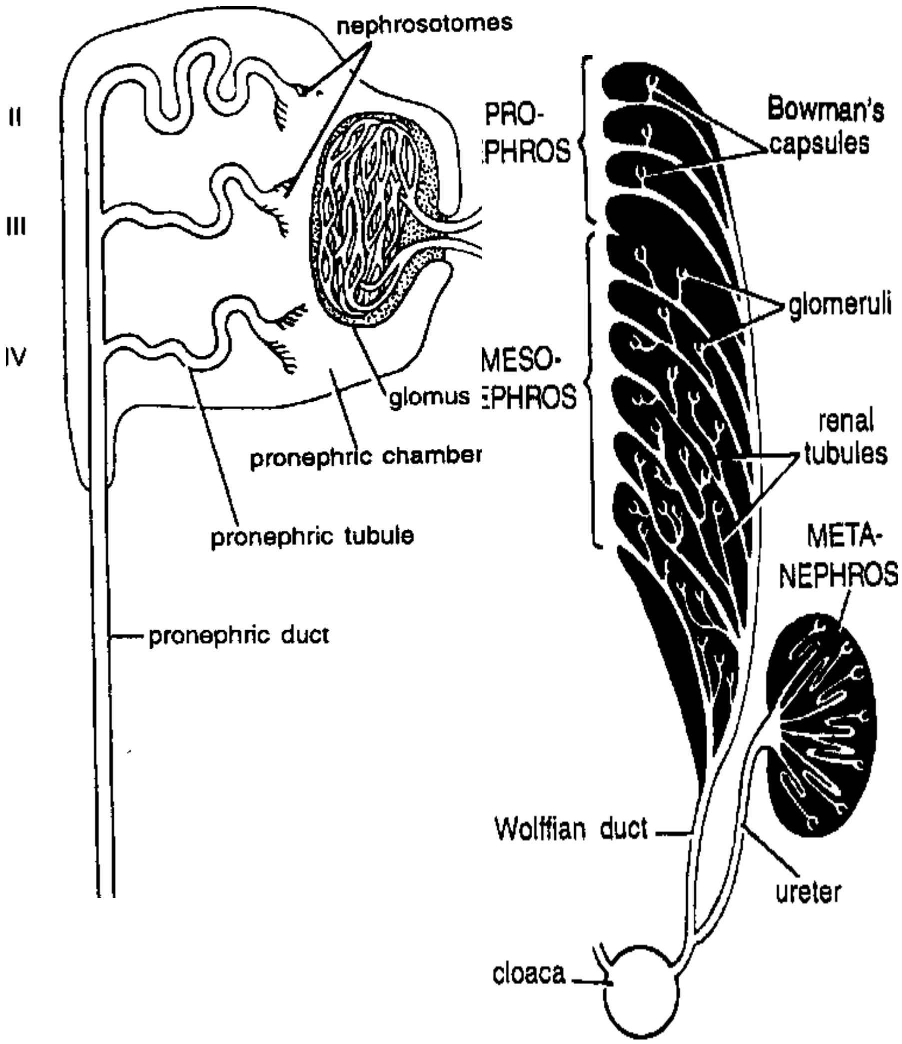


Fig. 3. Encapsulated pronephric kidney of 15 mm. frog larva

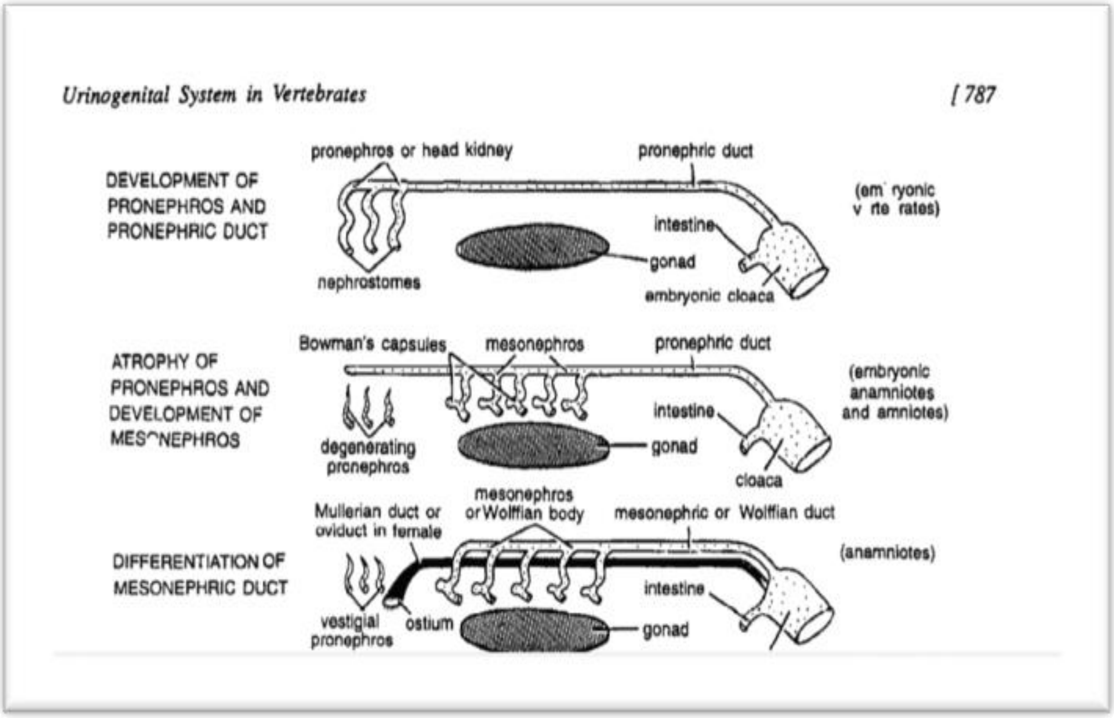


Fig. 4. Diagrammatic plan of pronephros, mesonephros and metanephros in vertebrates

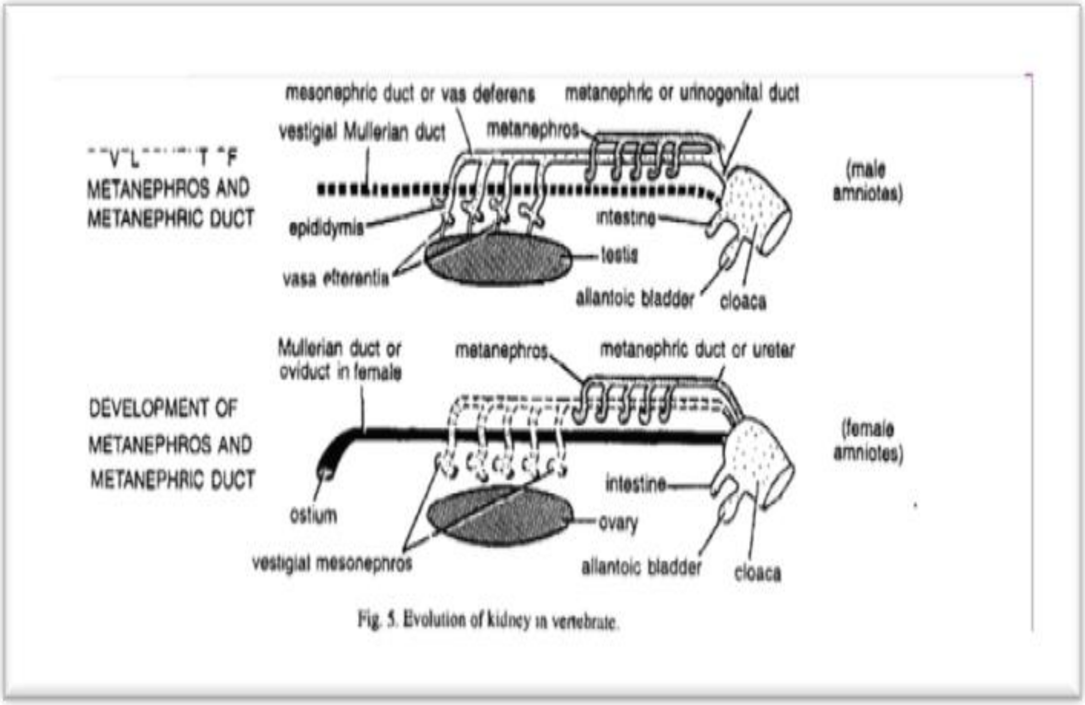


Fig. 5. Evolution of kidney in vertebrate

5-Metanephros. The functional kidney of higher vertebrates or amniotes is a metanephros. It is formed from the posterior end of the nephrogenic mesoderm which is displaced somewhat anteriorly and laterally. When metanephric tubules develop, all the mesonephric tubules disappear except those associated with the testis in male and forming vasa efferentia. The adult kidney (metanephros) of amniotes differs from that of anamniotes (mesonephros or opisthonephros) chiefly in:

(1) Its origin from only caudal end of nephrogenic mesoderm.

(2) In greater multiplication and posterior concentration of nephrons or tubules. They are particularly very large in number and highly convoluted in birds and mammals, hence the large size of kidney. It is estimated that each kidney of man is composed of about 1 million nephrons. The high rate of metabolism yields a large amount of wastes to be excreted.

4-In developing a new urinary duct, called metanephric duct or ureter. It is budded off from the base 'of the Wolffian duct(mesonephric duct). It grows anteriorly and dorsally, and eventually the metanephric tubules open into it. Its dilated distal tip forms pelvis which forks several times to become the collecting tubules. Its proximal portion becomes the metanephric duct or ureter that empties into cloaca or urinary bladder in mammals.

4-The mammalian metanephros shows greatest organization of all, with several additional features. A thin, U-shaped loop of Henle forms between proximal and distal convolutions of a metanephric tubule. Such loops are absent in reptiles and rudimentary in birds. Kidney shows an outer cortex with

concentration of renal corpuscles, and an inner medulla having collecting tubules and loops of Henle, which are aggregated intoone or several pyramids tapering into pelvis .Mammalian kidneys do not receive afferent venous blood supply as there is no renal portal system.

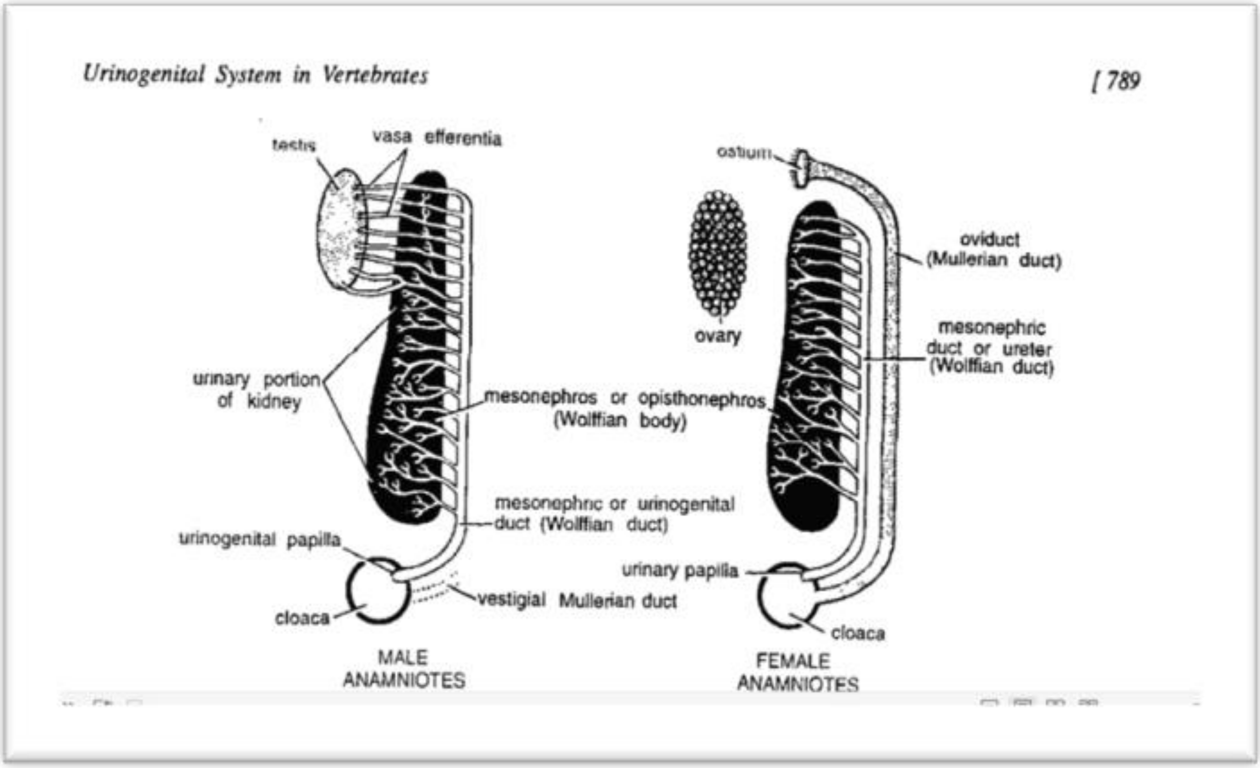
Urinary Bladders

Most vertebrates have a urinary bladder to store urine before it is discharged. However, it is lacking in cyclostomes, elasmobranchs, some lizards, snakes, crocodilians and most birds. In most fishes it is simply a terminal enlargement of mesonephric ducts and called a tubal bladder. In Dipnoi, it evaginates from dorsal wall of cloaca and is probably homologous to the rectal gland of elasmobranchs. In tetrapods, it evaginates from the ventral wall of cloaca. In amphibians, it is termed a cloacai bladder. In amniotes, the adult bladder is derived from the proximal part of embryonic allantois, hence called an allantoic bladder.

Kidney ducts or ureters generally open dorsally into cloaca. But in mammals, except monotremes, the ureters lead directly into the urinary bladder which opens to outside through a short tube, the urethra. Mammals lack a cloaca as the dorsal part of embryonic cloaca forms the rectum and the ventral part becomes the urethra.

Gonads and their Ducts

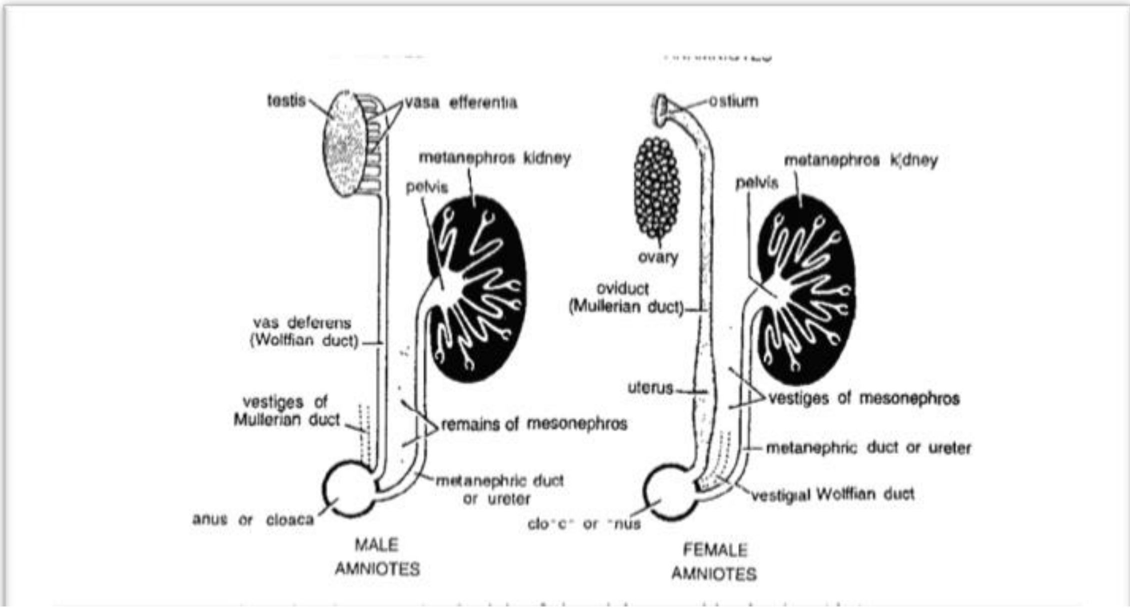
Reproduction is sexual in vertebrates, and the sexes are separate (dioecious) with the exception of hagfishes and a few bony fishes having a hermaphrodite gonad. Reproductive glands or gonads of males are called testes which produce the male gametes called sperm. Female gonads are called ovaries which produce ova. In the embryo gonads originate as a pair of thick elevated folds or genital ridges of coelomic epithelium from the roof of coelom, one on either side of the dorsal mesentery. Genital ridges are much longer than the functional adult gonads, suggesting that in the ancestral vertebrates the gonads extended the whole length of the pleuroperitoneal cavity. The functional adult gonad is derived from the middle or gonal part of genital ridge, while its anterior progonal and posterior epigonal parts remainsterile. Gonads remain suspended in coelom from dorsal bodywall by a fold of dorsal mesentery called mesorchium in males and mesovarium in females. Generally, one pair of gonads is present But, some vertebrates have a single gonad only because of either fusion of both embryonic genital ridges (most cyclostomes, perch and some otherfishes), or degeneration of one juvenile gonad)hagfishes, some elasmobranchs and lizards alligators and most birds). Associated with the gonads are special gonoducts or genital ducts, vasa deferentia in males and oviducts in females, to transport gametes to cloaca or to outside body .However, cyclostomes and a few elasmobranchs lack genital ducts. Their eggs and sperm escape body cavity via abdominal pores.



FEMALE

MALE ANAMNIOTES

ANAMNIOTES



FEMALE

MALE AMNIOTES

.**1-Testes and male genital ducts**. Testes of vertebrates are paired organs of moderate size usually found attached to kidneys. Each testis is a compact gland, covered by coelomic epithelium and composed of numerous highly coiled seminiferous tubules embedded in connective tissue. Tubules are lined by germinal epithelium which gives rise to billions of sperm. On maturity the sperm are set free in the lumen of tubules and move towards the genital ducts.

Some Cyclostomes have a single median testis without a genital duct. Sperms are released in the coelom from where they pass through abdominal pore, located at posterior part of coelom. In dogfish, the two testes are elongated bodies. In most anamniotes, the opisthonephros (or mesonephros) is differentiated into anterior genital and posterior renal portions. In the anterior genital portion in males, some uriniferous tubules lose excretory function, form slender vasa efferentia and become continuous with seminiferous tubules of the adjacent testis. They serve to convey sperm of testis to the mesonephric duct of kidney. Thus in male anamniotes, mesonephric or wolffian duct forms a urinogenital duct, serving both as a vas deferens for sperm as well as a ureter for urine However, in many elasmobranchs (e.g. dogfish) accessory urinary ducts drain urine from kidney to cloaca so that the mesonephric duct serves entirely or mainly as a vas deferens. The anterior genital part of kidney along with the part of mesonephric duct forms an epididymis.

In the embryos of Anura, each testis is made of two portions. In male frog, the anterior portion disappear and the posterior portion becomes the adult functional testis. In adult male toad, the anterior portion also persists as the Bidder's organ containing large cells similar to immature ova.

In male amniotes, a metanephros develops as the adult functional kidney with its own urinary duct or ureter to transport urine. Thus mesonephric or Wolffian duct becomes solely a genital duct or vas deferens. The remnants of embryonic mesonephros and a coiled portion of mesonephric duct become the epididymis of the adult kidney. From each testis sperms pass first through epididymis, then through vas deferens to reach urethra.

In most mammals testes descend permanently into extra-abdominal skin bags called scrotal sacs In rabbits, bats and rodents, they are lowered into sacs and retracted at will. Passage between abdominal cavity and scrotal sac, through which tfestis descends, is called inguinal canal. However some mammals such as monotremes, insectivores elephants, whales, etc., lack scrotal sacs so that their testes remain permanently intra-abdominal like ovaries.

3-Copulatory organs. Copulatory organs are absent in anamniotes, since they have usually external fertilization. But, in amniotes, fertilization is internal, and preceded by copulation or mating .Male amniotes usually develop intromittant or copulatory organs for transferring sperm into the genital tract of females, during copulation. They are particularly characteristic of reptiles and mammals.

In elasmobranchs (e.g. dogfish), bases of pelvic fins are modified as intromittant organs called claspers. These are grooved, cylindrical structures that are inserted into the female cloaca to inject sperm. In dog, fishes and some allied forms there is blind muscular sac called siphon located at the base of claspers. This sac gets filled] with sea water which is used to force the spermatic fluid into the cloacae of female. In several teleosts, the anal fin is modified as a gonopodium for sperm transport. It is modification of anal fin. Snakes and lizards have a pair of retractile, grooved and sac-like hemipenes which can be everted through cloaca. Their retraction is controlled by modified body wall musculature.

Turtles, crocodilians, some birds (drakes, ganders,ostriches) and prototherian mammals have an unpaired, grooved and erectile penis formed as a thickening of cloacal floor. Only higher mammals have a true external, erectile penis with a tubular groove continuous with a spongy urethra. A series of accessory sex glands associated with penis secrete a fluid in which sperm are carried.

3-Ovaries and female genital ducts. In female anamniotes, ovaries are large, occupying much of the body cavity and produce thousands of eggs as fertilization is external. In amniotes ovaries produce fewer eggs because fertilization is internal. Ovaries of reptiles and birds are still large and the eggs produced contain much yolk .However, mammalian eggs contain very little yolk so that their ovaries also remain quite small. Ovaries are generally paired structures, but only a single median ovary occurs in cyclostomes as also in some teleosts (e.g. perch). They are not attached to kidneys like testes in the males. Only the right ovary is functional in many elasmobranchs, whereas only the left ovary becomes mature in birds and some primitive mammals (e.g. Ornithorhynchus).

Histologically, an ovary is a mass of connective tissue with an outer layer of germinal epithelium showing ova in various stages of development. Ovaries are hollow and saccular in fishes and amphibians but compact in amniotes especially in mammals, in which each ovum is surrounded by a follicle. Mature eggs are released either internally into the central ovarian cavity (teleosts) which is continuous with the lumen of the oviduct, or extruded externally into the surrounding coelom or bodycavity (Tetrapoda). This process is termed ovulation. In all vertebrate embryos, except cyclostomes the coelomic epithelium on the outside of mesonephric duct develops a groove which becomes closed to form a tube called Mullerian duct. In adult males, Mullerian duct becomes vestigial and functionless. In adult females, it grows larger and becomes the female genital duct or oviduct. It opens anteriorly into coelom, in the region of degenerating pronephros, by a coelomic funnel or ostium, and terminates posteriorly into cloaca. In female elasmobranchs, the Mullerian duct is formed differently by the longitudinal splitting of the pronephric duct.

Thus, in adult female anamniotes, both the Mullerian duct)oviduct) and the Wolffian duct (mesonephric or urinary duct) are present. But, in adult female amniotes, with the development of adult metanephros and its metanephric duct or ureter mesonephros and its duct (Wolffian duct) degenerate leaving only vestiges known as provarium.

In viviparous mammals, posterior ends of both the Mullerian ducts become fused and are modified into a uterus in which the embryos develop, and a vagina which receives the male intromittant organ during copulation. The remaining anterior parts or oviducts are relatively short, narrow and convoluted and called the fallopian tubes. Condition of uteri varies in different mammals. When uteri remain double without fusion, it is called duplex uterus (marsupials). When uteri partially fuse so as to form two horns and two separate lumens inside, it is called bipartite uterus (hamster, rabbit). When there are two horns but a single internal cavity it is termed bicornuate uterus (ungulates). When uterine horns are absent and both uteri fuse completely with a single internal cavity, it is termed simplex uterus (Primates, some bats, armadillos).

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